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## LESSONS DRAWN FROM THE HISTORY OF SCIENCE.[1]

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It is with some misgivings that I enter upon a discussion which involves questions of history. The teacher who seeks light does not usually look back upon the dingy past, but moves forward in the endeavor to catch the first rays of a new day. But in so doing he must not forget that a knowledge of the past experiences frequently enables him, when in the jungle, to recognize the points of the compass, and the direction toward the rising sun.

The teacher of mathematics has long recognized the aid he may derive from the study of the history of his science. The herology of the history of physics has been found to stimulate interest. There are signs of an increasing appreciation of the history of chemistry and other natural sciences. Last December an eloquent plea was made before the American Anthropological Association for the study of the history of medicine and natural sciences. European recognition of the importance of this study is seen in the fact that the universities of Berlin and Vienna have each two professors for the history of medicine.

Of the twentieth century we are told that "one of its primary tendencies has been towards a restoration of our lost connection with the eighteenth centuy and with earlier periods, resulting in a movement of such earnest and impressive character that we cannot foretell at the present moment whether the eighteenth century will not, at some day not far off, seem nearer to us than the sober prose of the nineteenth."[2] It is my purpose to consider the relation of the present to previous centuries, and to see what lessons may be drawn from such a retrospect. I trust that you will bear with me for five or ten minutes if by way of illus-

[1] Read before the general meeting of the Central Association of Science and Mathematics Teachers, at St. Louis, Nov. 29, 1907.

[2] *Science*, June 7, 1907, p. 890.

tration, I make a rapid historical survey of a special topic in elementary geometry, namely, of the subject of areas of polygons and of curves. In considering the concept of area, no one doubts that the ancient Egyptians had just as clear an idea of the area of a piece of land as the Yankee boy has of the size of the American dollar. Yet, at the time of the building of the pyramids the Egyptians knew no science of geometry. Their ideas were purely intuitive. When it came to the numerical calculations of areas, or as we might express it, to the arithmetization of the areal concept, they were greatly at fault; their formulas being only crude approximations. More successful attempts at the arithmetization of the area-concept were made by the early Babylonians who, as shown by the recently discovered Nippur Tablets,[3] had the correct rules for finding the areas of squares, rectangles, right triangles and trapezoids. The long epoch of empirical geometry of areas was succeeded in the time of Pythagoras by a period which made appeals to reason. Two of Euclid's propositions on areas (Prop. 28 and 29 in Bk. VI.) are attributed to the Pythagoreans, while Pythagoras himself constructed a figure equal to one and similar to another given figure, and proved the theorem of the three squares, known by his name.

But the treatment of areas was still one-sided. Greek geometry before Archimedes eschews all mensuration, all arithmetization of the area-concept. With Archimedes comes deeper insight. In his work on the *Sphere and Cylinder*, he stated explicitly as an assumption what before him everyone had felt to be true, but had never explicitly set forth as an assumption, namely: that, in the case of two unequal lines, surfaces, or solids, there exists a certain multiple of the lesser which exceeds the greater. This is the famous postulate of Archimedes. It asserts that it is possible, for instance, by taking a sufficient number of steps, to cover the distance of a block. Without it the number $\pi$, as the expression of the ratio of the circumference to the diameter, has no meaning. In a non-Archimedean geometry, which assumes that this postulate does not hold, it would be possible to take upon a segment an arbitrary number of steps without reaching the end of the segment. Such a state of discontinuity lies outside the sphere of our experience. With Euclid the

[3] H. V. Hilprecht, *Mathematical, Metrological and Chronological Tablets from the Temple Library of Nippur*, published by the Babylonian Expedition of the University of Pennsylvania, 1906. Reviewed in Bull. Am. Math. Soc. Vol. XIII, 1907, p. 392.

Archimedean postulate is hidden in one of the definitions (Def. 4, Bk. V.). "Magnitudes are said to have a ratio to one another, when the less can be multiplied so as to exceed the other."

As long as an argument involves assumptions which are not explicitly set forth in the mind, the logic is imperfect. We are dealing with syllogisms without a major premise and we are to the extent of that practice really not making deductions at all, but are merely giving expositions of the facts of our experience. To say that John Smith is a mining man, and therefore a gambler, may be a true description of the man, but the statement is no syllogism, unless there is a major premise, such as, that all mining men are gamblers. If this general statement is found untrue, then further specifications are in order for a precise presentation of the case. In all Greek geometry, it is tacitly assumed as self-evident that polygons and all closed curves in a plane possess area. But we know now that this is not true of all closed curves.

The need of defining the concept *sum, greater, less* in connection with areas and other geometric quantities was first emphasized about forty years ago by the Frenchman, Duhamel.[4] It must be shown that figures, especially those which are unlike in form, are capable of comparison with respect to content. I pass by a considerable number of able writers on this subject and come down to Hilbert[5] of Göttingen. In the effort to be specific and at the same time to get along with the least possible number of postulates, Hilbert and other geometers have found it desirable to distinguish between polygons having equal content and those having equal areas. Two polygons have equal area if they are made up of the same finite number of parts, congruent in pairs. Two polygons are of equal content, if other polygons equal in area can be added to each, so that the resulting polygons are equal in area. From this last definition it follows easily that two parallelograms of equal base and altitude have equal content. Hilbert was able to prove all of Euclid's theorems on content without the use of the Archimedean postulate. But Hilbert, Halsted, and other authorities agree that without the postulate of Archimedes it is not possible to prove the simple theorem that two triangles having equal base and equal altitude, are equal to each other in area.

[4] *Des méthodes dans les sciences de raisonnement*, Paris 1865-68, 2, p. 445. See also *Encyklopaedie der Math. Wiss.* III A B 1., 10.

[5] *Foundations of Geometry* by D. Hilbert, transl. by E. J. Townsend, 1902, § 18.

When it comes to plane surfaces bounded by *curves* the problem is still more difficult. We must resort either to the method of exhaustion of the ancients or to the theory of limits. But it is not self-evident that a closed figure in a plane has a definite area. In fact, a few years ago Osgood[6] of Harvard gave an example of a closed curve in a plane, confined in a finite region, which has no definite area. This fact calls for all sorts of precautions in reasoning. The theory of area is closely related to the theory of curves which bound these surfaces. On the subject of curves, other startling results have been reached, which have swept the naive intuitionalists off their feet. The critical school of mathematicians have discovered curves, that are continuous within certain intervals, yet possess no length and have no tangent lines.[7] It has discovered curves, the so-called surface-filling-curves, which are continuous curves containing every point in a square. To the naïve intuition these results of abstract thought are incomprehensible. A curve has been defined as the path of a point, but in view of the startling results just named, it is desirable to restrict the definition. No one method of restriction has as yet been generally agreed upon, and we have the rather unique spectacle of mathematicians being divided in the definition of a curve, after two thousand years of assiduous study of geometry.

In the historical evolution of the area concept we have an illustration of how visual perception was very prominent at first, but was gradually replaced by logic. The successive stages from crude intuition to rigorous logic may be imagined in the form of huge steps as represented by successive ranges of mountains viewed from the distance. From the plain in front rise the foothills and beyond tower successive elevations, appearing in the form of a gigantic stairway, leading to the highest elevations of abstract thought. The instructive part of all this is that the advance has not been by one sudden rise to the topmost elevation, but through several successive stages like an echelon.

This echelon mode of progress might have been seen in other concepts than that of area. It might have been seen in the concept of length of a line, or still better, in the general attainment of our knowledge of the axioms of geometry or of algebra.

Do these considerations carry any lessons to the teachers of

[6] Trans. Am. Math. Soc. Vol. 4, 1903, p. 107.

[7] See *Encyklopaedie d. Math. Wiss.* III A B 2, 8, or F. Klein Anwendung der Diff. u. nt. Rechnung auf Geom., Leipzig, 1907, p. 238, etc.

to-day? If we are justified in assuming that in many respects the experience of the race, and of the individual coincide, then there can be no doubt. Biologists teach that the human being goes through the same physical development as do the animals immediately below him. The embryo develops echelon fashion through successive steps common to the lower animals.

The detection of a corresponding law respecting intellectual growth is more difficult, but the belief in its existence has been entertained by such men as Pestalozzi, Herbert Spencer, Felix Klein and Poincaré. This law may be stated as follows: The individual passes through the same general stages of intellectual growth as did the race. If, therefore, we are familiar with the history of thought in the race, we can predict the most natural course of ascent in the individual. Considering then the teaching of geometry, history tells us to rely greatly upon intuition in the early stages, and to make no sudden and abrupt change to severely rational demonstration. Modern critics warn readers to take no notice of geometric figures or diagrams. Among them, geometry without diagrams is the order of the day. This is the very highest step in the echelon of geometric abstraction. In my judgment it should not be attempted at all in secondary education, but should be postponed until the advanced college and graduate courses. I claim that it would be a mistake in early secondary courses to attempt the consideration of "betweenness assumptions" or of the Archimedean assumption of continuity. It would be a mistake to require a beginner to prove that a sect in a plane polygon cuts the polygon if sufficiently produced. Intuition yields these results instantaneously, and the pupils' relish in the exercise of intuitive power should not be rudely shattered. For logical puzzles he has as little sympathy as had Diogenes for the argument put before him by a sophist to the effect that motion was impossible. Diogenes refuted the argument, not by abstract logic, but simply by getting up and walking around his tub. I cannot forbear repeating for the benefit of those who favor ultra-rigor in high school mathematics a verse quoted by Professor E. W. Brown:

"The centipede was happy till
One day the toad in fun
Said, 'Pray, which leg comes after which?'
This raised his thoughts to such a pitch,
He lay distracted in the ditch,
Not knowing how to run."

Let the young child temporarily accept as self-evident, theorems which appeal to his intuition. A few months after he will, under skillful leadership, begin to feel the need of increased rigor. He, himself, will rise one step higher in the echelon toward making mathematics more mathematical.

Before long the honest pupil will crave a still greater perfection in reasoning, and he rises a second step higher. He will thus be ascending of his own free will the same stairway which the race has been climbing during historic times. It should be the duty of the teacher to encourage the pupil to rise in the echelon to higher and higher levels of ratiocination. But it is here, where in past ages teachers have failed. In England, where Euclid has held sway until recently, the pupil was placed from the very start on a high level, and he was seized by dizziness in the rarified air of abstract logic.

As early as 1570, when the study of geometry was at a low ebb in the universities, Sir Henry Savile, Warden of Merton College in Oxford, endeavored to create an interest in the subject by giving a course of lectures on geometry. He confined himself mainly to the early part of the first book of Euclid, and he endeavored to present the fundamental ideas to untutored minds with all the rigor known to his day. On concluding the course he used the following language: "By the grace of God, gentlemen hearers, I have performed my promise; I have redeemed my pledge. I have explained, according to my ability, the definitions, postulates, axioms and the first *eight* propositions of the Elements of Euclid. Here, sinking under the weight of years, I lay down my art and my instruments."[8] Need we marvel if sinking under the weight of logical and philological subtleties, the pupils failed to exhibit marked enthusiasm for geometry?

In Germany and France where for long periods of time, in former centuries, text-books like those of Clairaut, Lacroix and Kambly were used, no pretension was made at rigor of demonstration; the pupil was kept on the level of crude intuition all the time. There was no effort to lead him on to greater perfection in reasoning; no effort was made to scale mountains. Both modes of procedure are radically wrong.

The historic and, I believe, the pedagogic method is to start at the bottom with sense-perception, with the "art of handling

[8] W. Whewell *Hist. of the Ind. Sciences* Vol. I, New York, 1858, p. 205. See also Cajori *Hist. of Elem. Math.*, New York, 1896, p. 281.

the rule and compasses," and then gradually to rise to higher levels of abstraction.

"Thus the inner world grows wider as the outer disappears
And the soul, retiring inward, finds itself beyond the spheres."

The present day tendency in England appears to be in the right direction. There is no evidence of an alignment with the modern critical school of mathematicians. The British are coming to view school geometry more from the *genetic* standpoint and less and less from the severely *logical* standpoint.

You may wish me to support my views with the authority of great names. There is perhaps no greater living mathematician than Poincaré. He says that one cannot blame writers of textbooks for lack of rigor.[9] "They are obedient to necessity; the beginner is not prepared for real mathematical rigor; he would see therein only useless and wearisome subtility in trifles; it would be a waste of time to lead him prematurely to more pretentious efforts; he must run rapidly the course which the founders of the science have surveyed leisurely, but in so doing he must keep in mind continually the distances he has passed over." Had I time I could add to the testimony of this great Frenchman the testimony of a great German. No one has been more prominent during the past fifteen or twenty years in furthering mathematical education than Felix Klein of Göttingen. Many gifted young men of America have gone to Germany to sit at the feet of this modern Gamaliel. Felix Klein has been interested in Americans, and during the World's Fair in Chicago he delivered in Evanston a series of lectures on mathematical subjects. Not only does Klein believe in intuition for elementary mathematical instruction, but he believes that even the mature mathematician, when engaged in research, cannot dispense with it. ("Evanston Colloquium," p. 45.)

There are cases on record where great men have resorted not only to intuitional, but also to experimental mathematics. Galileo, to whom we owe the name "cycloid" and who is probably the inventor of this graceful curve, found the approximate area of the cycloid by cutting it and the generating circle out of cardboard, and then weighing each piece. He found that

[9] We are quoting from F. and L. Lindemann's German translation of Poincairè's *Wissenschaft und Hypothese*, Leipzig 1906, p. 5. A translation from the French into English has been made by G. B. Halsted.

the cycloid weighed nearly three times as much as the generating circle.[10] This incident is interesting, since it illustrates the possibilities, and also the limitations of experimental mathematics. Experimentally, Galileo was not able to show that one area was exactly three times the other; in fact, he believed that the two areas were incommensurable. Undoubtedly the laboratory method of teaching mathematics has its advantages, but it has also its disadvantages. Experimental errors frequently conceal the simple relations actually existing. Moreover, the pupil is in danger of concluding that geometry is made up of relations that are mere approximations.

Does history throw out any hints on the teaching of algebra? The first traces of algebra are found in the Ahmes Papyrus and the cylindrical tablets of Nippur, both dating from about 2,000 years B. C. Algebra was deeply pondered by Diophantus, by the Hindus and Arabs, by the mathematicians of the Renaissance, but only during the past hundred years have the fundamental laws of algebra been the subject of serious contemplation and successful treatment. The mathematicians of the eighteenth century, including Euler, Lagrange and Laplace, did not give proofs. now considered satisfactory, of the rule that the product of two negative numbers is positive, for the reason that they did not explicitly assume as major premises the requisite fundamental laws of algebra. At no time in the history of geometry has there been such restlessness, such groping in the dark as there was in algebra during the eighteenth century. Negative and imaginary numbers gave rise to endless debate. Not until Wessel, Argand and Gauss discovered a graphic representation of the imaginary number did the storm abate. Greater rigor came with the famous researches of D. F. Gregory, De Morgan, Peirce, Hamilton, Grassmann, Kronecker and Cayley.

Do these facts point a moral? When ten or a dozen years ago one of our large publishing houses brought out a beginner's algebra, which gave on the first few pages a discussion of the associative, distributive and commutative laws, I began to wonder what the success of the book would be. Before very long a second edition appeared, in which no mention of these laws was made. The *systematic* mode of exposition was forced

[10] See Cantor *Gesch. d. Mathem.*, Vol. 2, Leipzig, 1892, p. 810.

to yield to the *genetic*. The interest of a schoolboy does not lie in severely logical exposition.

Mathematicians of the Renaissance fairly rioted in the application of algebra to the solution of problems. Even earlier, Diophantus and the Hindus took delight in problem working. Says Brahmagupta (628 A. D., p. 100): "These problems are proposed simply for pleasure; the wise man can invent a thousand others, or he can solve the problems of others by the rules given here. As the sun eclipses the stars in brilliancy, so the man of knowledge will eclipse the fame of others in assemblies of the people, if he solves them." Has this sentence from Brahmagupta, written twelve centuries ago, no lesson for us? Without concerning himself with the nicer question of fundamental principles, he revels in doing things. Our boys and girls enjoy algebra best when they are *doing* things, when they are solving concrete problems. For mind training, is not the concrete side of arithmetic and algebra more efficient than the abstract? The concrete side affords an unlimited variety of exercises, simple in logic, while the abstract side contains very little which comes within the pupil's sphere of interest and comprehension. We are breaking away from the ideal of the Massachusetts teacher who boasted: "My pupils may not know the multiplication table, but they know something far more precious, the meaning of multiplication."

Another point is made clear by history. In the Babylonian tablets and the Egyptian papyrus of four thousand years ago, arithmetic, algebra and geometry are not segregated; they appear as one. We do not always quite know whether we are reading arithmetic, geometry or algebra. Algebra and geometry originated simultaneously and served as a mutual stimulus to rapid development. Evidently the "correlation" of the different branches of elementary mathematics is not an idea that originated in America, or that had its birth in the nineteenth century. It is coeval with mathematics itself. Much of our discussion on correlation and other methods of teaching is merely an effort not to lose the acquisitions of previous ages. It is an effort to ward off an era of pedagogic decadence; it is the annual renewal of our ideals. In the hands of a skillful teacher, correlation has always proved to be a fruitful idea. By skipping and sampling and pressing the keys lightly until something is touched that absorbs the interest of the pupil, great results are reached.

But when subjects are dwelt upon which do not come within the pupil's interest and experience correlation becomes a dangerous expedient. The correlation of algebra and geometry as exhibited in graphic work has great possibilities and great dangers. Ultra enthusiasm for refinements in graphics may be as dangerous as is ultra conservatism. To systematically introduce into a course in elemetary algebra problems in specific gravity, specific heat, accelerated motion and kinetic energy is a practice fatal with young pupils in a high school. With pupils who find algebra hard, and have no grasp of physics, a correlation of this sort is a pedagogical blunder. The correlation should be of a kind that will help, not hinder; illuminate, not befog. A correlation of algebra and arithmetic, of algebra and geometry precedes historically the correlation of algebra and physics. The latter represents a more advanced stage of abstraction. Correlation, like liberty, may be a blessing or a curse, according to the mode of its application.

The echelon mode of advancement is noticed also in physics. Mechanics was at first empirical. The builders of the pyramids achieved marvels without knowing Newton's three laws of motion. Take the theory of the lever. The correct principle was given by Archimedes, but with him the intuitive element figured largely. Later followed more careful study of the underlying assumptions. The principles of mechanics were unraveled very slowly, notwithstanding their importance in practical life. Great intellects like Galileo, Descartes, Huygens and Leibniz were divided on elementary questions. Galileo successfully mastered the first and second laws of motion. Descartes' statement of the third law was false in substance. The motion of bodies in direct impact was imperfectly understood by Galileo, erroneously given by Descartes, and first correctly stated by Wren, Wallis and Huygens. Descartes had no true notion of acceleration, and in that respect did not rise as high as Galileo had risen before him. Then began a curious dispute between the followers of Descartes and the followers of Leibniz on the measure of the efficiency of a moving body. Descartes took this efficiency to be proportional to the velocity, considering the time during which it acted; Leibniz took it to vary as the square of the velocity, considering the distance through which it acted. The controversy lasted over a half a century, until D'Alembert finally showed that both parties were in the right, but were

considering this abstruse question from different standpoints. In view of this long battle of giants need we marvel if our boys and girls find it difficult to grasp the abstract ideas of physics? Need we worry over the fact that such is the case? Should we not cheerfully submit to the necessity of leading the pupil into the subject gradually and of allowing him time to absorb the new ideas? Do not fret over failures to reach immediate results in the algebraic solution of problems in mechanics. Do not get excited if the pupil fails to discriminate between weight and mass. Galileo, Descartes, Leibniz and Huygens had no clear notion of mass; by them weight and mass were taken interchangeably. In fact even the scientists of our own time are far from satisfied with their present day mass-concept. And when I say these things, I do not mean to advocate laxity. I have as little sympathy as had Cardinal Newman[11] for a theory of teaching in which "learning is to be without exertion, without attention, without toil, without grounding, without advance, without finishing." I believe in exacting requirements, but also in the exercise of discretion as to the choice and order of topics, and as to the time required for their absorption. In considering the tremendous strides which have been made in the advancement of laboratory courses in physics, there is one caution that I venture to make. Historically, qualitative results in any particular branch precede quantitative. The pupil's acquaintance with physical phenomena is usually limited. Hence the need of repeating the great qualitative experiments of physics. Count Rumford made water boil by the heat of friction half a century before Joule began his precise measurements on the mechanical equivalent of heat. We must not emphasize exact measurements prematurely. Exactness came late in the history of the science; it comes late in the growth of young minds.

This fact may be illustrated by a story. As late as the seventeenth century two Frenchmen (Mersenne and Petit) fired bullets vertically upward, expecting them to strike the ground far to the westward, but the bullets could not be found. Thereupon Descartes, who was the French oracle of that time, was consulted, and he seriously replied that the bullets had received such intense velocity that they lost their weight and flew away from the earth. An erroneous judgment like this is on a par with that of a young girl who in the laboratory hesitated to

[11] *The Idea of a University*, London, 1893, p. 142.

touch a Le Clanché cell, fearing that she might receive a mortal electric shock. Simple qualitative experiments can correct the judgment in most cases like this; in others measurement and computation become necessary. While a certain amount of measurement is desirable in a good high school course, it should nevertheless be recognized that the pupil is not yet sufficiently advanced to profit by a severe course on precise measurements. The mind of a high school boy is at first little more than a receptacle for information of every kind; he heaps up all sorts of knowledge as a treasure for a future day. As Cardinal Newman puts it, these years are "the seven years of plenty with him. He gathers with handfuls, like the Egyptians, without counting." Somewhat later comes a higher step in the echelon of progress, which brings the reduction of the heaps of facts into order and system, and a more intense exercise of his intellectual power in the critcal study of exact relations.

In closing let me say that I do not look upon history as a universal and infallible guide in pedagogy. I see clearly that a blind follower of the historic plan would at times be led into evident absurdities. No one nowadays would follow the historical order and teach logarithms before the theory of exponents. We are able to take occasional short cuts which the race in its advancement overlooked. But I feel that the contemplation of the echelon development of the different sciences carries with it suggestions which it is worth while for us to test in the light of reason and experience. "He who reads attentively will discover the threads of gold which run throughout the web of history."

GROUP OF A PORTION OF THE PEOPLE WHO ATTENDED THE ST. LOUIS MEETING OF THE CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS.

Picture taken from main entrance of McKinley High School.

## THE MISSOURI BOTANICAL GARDEN.*

By William Trelease.

Origin and History.—Henry Shaw, an Englishman who amassed a fortune in St. Louis and has left it in an endowed establishment that will constitute his enduring monument, conceived and put into shape a beautiful flower garden in 1849; this he lived to enjoy and share with the public for forty years. Meantime, through the counsels of Engelmann, Hooker and Gray, he broadened his plans so as to provide for its perpetuation for public use and benefit on a much larger scale than he had at first contemplated.

Purposes.—These plans, as outlined for the trustees to whose administration his property is left, comprise the instructive and attractive demonstration of plants in large variety, the training of botanists and gardeners, and addition to knowledge about plants, by investigations.

The garden, through which these ends are to be reached, occupies about half of a tract of 125 acres, and is now appraised, with its improvements, at about three-quarters of a million dollars. In it are grown, in natural planting, formal beds, ponds, rockeries, or under glass, not far from 18,000 species and varieties of plants. So far as conditions permit these are arranged instructively, and labeled with common and scientific names, and geographic range. Attractive planting is never lost sight of when it is possible, and the spring display in tulips and the fall display of chrysanthemums are counted among the notable floricultural events of the country each year.

By Mr. Shaw's provision, the Director of the Garden is at the head of the School of Botany which he also endowed, and which, in addition to affording undergraduate instruction as a department of Washington University, offers facilities for graduate work leading to the degrees of Master and Doctor in the same University. Gardening instruction is provided for in a four years' course of combined study and manual work; and six scholarships open this course without any expense whatever to a like number of worthy young men. Research in various branches of botany, horticulture and entomology receives a small but continuous part of the time and effort of capable employees.

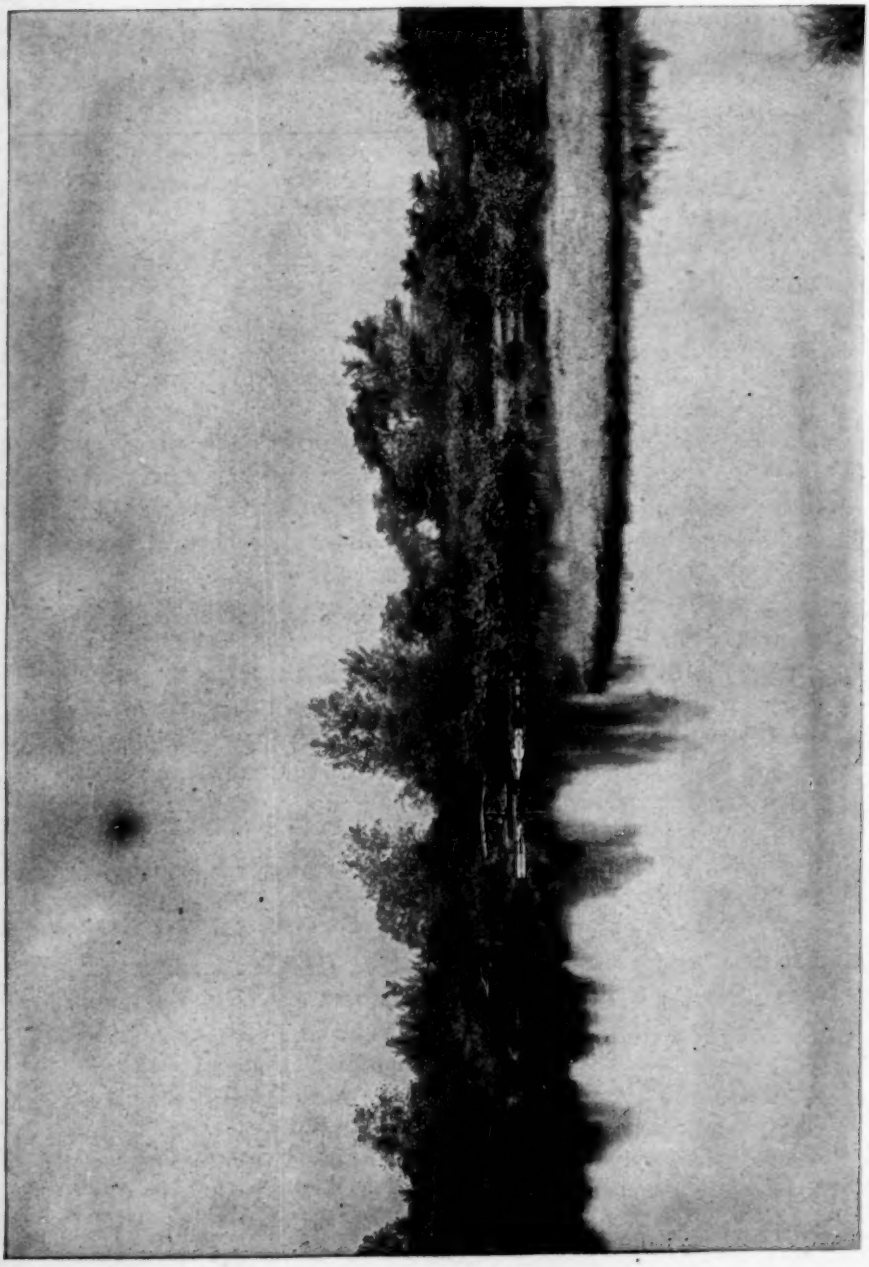
*The substance of a short informal address before the Biological Section of the Central Association of Science and Mathematics Teachers at St. Louis, Nov. 30, 1907.

EQUIPMENT.—The collection of living plants, in which orchids, bromeliads, cycads, yuccas, agaves and cacti are especially largely represented, possesses particular value because of a careful system of recording the history of individual specimens, each of which bears on its label a key number to its record. In the cactus, cycad, and acacia houses, especially rare and striking morphological demonstrations are afforded. Even such horticultural forms as mushrooms, figs, and hothouse grapes are grown with the care given to geraniums or orchids, and with equal success.

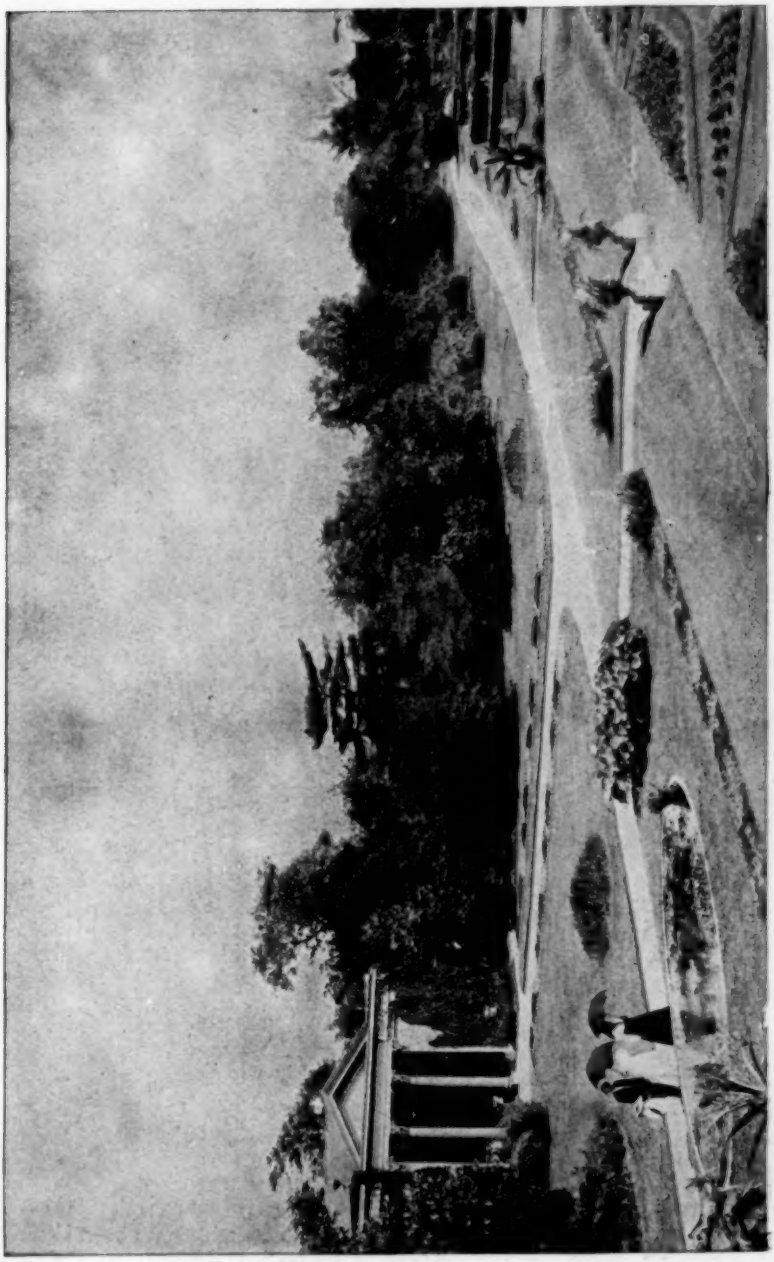
The first purpose in the early years of the Garden has been to lay a substantial and ample foundation in the two prime requisites of a botanical research institution: collections and books. In both herbarium and library this purpose has been met unusually well, and both are still rapidly growing. The former already contains over half a million specimens valued at nearly $85,500.00, and includes the herbaria of Bernhardi, Engelmann, Redfield, Reverchon, Eggert and other well known collectors, as well as much authentic material which formed the working nucleus of Chapman's herbarium when his flora of the southern States was written. The library contains more than 58,000 books and pamphlets, valued at over $90,000.00, and counts among its treasures a very large collection of publications dating from before the time of Linnæus, large files of serials, numerous rare issues, and, choicest of all, 60 thick volumes of manuscript notes and sketches made by Engelmann with painstaking care during the prosecution of his studies of the plant groups in which he was a master. An index of over half a million cards, though inadequate, renders the library much more usable than it would be without this aid.

PRODUCTIVITY.—The effectiveness of the Garden in reaching the general public can hardly be measured except by the number of visitors to it and the questions they ask. They average over 100,000 a year, and frequently ask questions that show that intelligent interest is awakened. Numerous classes of school children are among them.

As an educational factor, the School of Botany has figured to the extent of training a small but yet considerable number of Masters and Doctors of whose subsequent attainments there is reason to be proud. The school of gardening has equal reason to take pride in the professional standing of its graduates.



A TYPE OF NATURAL GARDENING AT THE MISSOURI BOTANICAL GARDEN



A TYPE OF FORMAL GARDENING AT THE MISSOURI BOTANICAL GARDEN

In research, small as is the time, as yet, that can be spared for this fascinating duty by those charged with a full load of administrative work, the eighteen yearly volumes of the garden Report show that results commensurate with their opportunity have been achieved by a number of investigators; and the collections of the Garden have been used as the foundation of many equally comprehensive studies carried on or published elsewhere.

FOUNDATION.—The endowment of the Garden consists mainly in real estate. Some of this is unproductive and the taxes on it are burdensome; but the foundation is appraised at some $3,000,000.00, and the maintenance income promises to increase rapidly and largely in the future. The gross revenue has averaged thus for about $111,000.00 a year. For years the expenditures were kept five or ten per cent below the income, as a provision for heavy property expenses that were foreseen. The garden is now in the throes of meeting street and sewer expenses; but there is an end to all things, and the heaviest of these for the present are nearly over.

On the income, Mr. Shaw placed a small fixed lien—which thus far amounts to about 3 per cent of the average gross revenue—in the form of bequests, all tending to further the purposes of the garden. General and special taxes have brought the unavoidable deduction up to 39 per cent of the average income. The (small) expense of administering the endowment property, and the (necessarily considerable) cost of maintaining the improved revenue property, increase this subtraction to about 56 per cent of the gross income, thus far.

The remaining 44 per cent has been spent on the Garden, for enlargement, improvements, maintenance, and productivity. The allotment of $45,300 for the present year may serve as an approximate index to the apportionment of the usual expenses, aside from large improvement:

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| Gardening | $28,500.00 = 63 % |
| Garden pupils | 1,200.00 = 2½% |
| Herbarium | 2,200.00 = 5 % |
| Library | 4,700.00 = 10 % |
| Office | 6,300.00 = 14 % |
| Research | 2,400.00 = 5½% |

FUTURE PROSPECTS.—As far as can be seen, the foundation of the establishment is secure, and adequate to the achievement of large results as time goes on. It is evident, though, that these

must be reached gradually and not by large jumps. The trustees have already increased the original area of the grounds by one-half, and detailed plans exist for the improvement of additional land that will double the present area. The plant houses have been doubled in size, though other and better ones are badly needed. One fireproofed building has been erected, but it is crowded to the ceilings. Meeting future needs is not left to chance. Plans exist for all; bit by bit the improvements most needed are being made as parts of these general plans, and the units are so arranged as to fall individually within the probable financial possibilities, so as to produce gradually an aggregate result obviously impossible of achievement by a single effort. That the already large equipment for research will be made much larger is certain. Increased available revenue, however, promises to open the way for a very essential factor in development—men. What the garden has thus far become in the scientific and educational world, it has become through its men. Its future and larger reputation depends equally upon the men who shall utilize its purely material facilities; with their increase its efficiency should increase at a rate far beyond the proportionate cost that their salaries will represent.

POLICY.—I have spoken at this length about the garden that force might be given to a closing word on its policy. This has been, is, and I venture to say always will be, that of helpfulness.

There is little wastefulness in administration. Even bedding plants that have to be discarded in the autumn are resuscitated in cold frames and distributed, to the number of a thousand or two every year, among the kindergartens of the city schools, and one of the pleasantest features of the annual chrysanthemum show is the distribution of the plants and flowers that remain at its close, among hospitals and charities. Many a teacher owes the plant equipment of his classroom or laboratory to the garden, and within its purpose and powers any service that it can render has only to be asked for.

## THE ATOMIC WEIGHT OF RADIUM; A NEW DETERMINATION.*

By Mme. Curie.

The determination of the atomic weight of radium which I published in 1902 (*Comptes Rendus,* July, 1902) was carried out with 9 centigrammes of radium chloride. Fresh processes having since then furnished some decigrammes of practically pure chloride, I have subjected them to purification, which enabled me to obtain 4 decigrammes of perfectly pure radium chloride, and to determine the atomic weight of radium under far better conditions than before.

The purification processes consisted as before in fractional crystallization in water containing hydrochloric acid, or in fractional precipitation of the aqueous solution by alcohol. The progress of the fractionation was controlled by photographs of the spark spectra, obtained with the spectrograph which formerly belonged to Demarcay. It is convenient to compare the relative values of the lines 4554.4 of barium and 4533.5 of radium. These lines, which are very close together, are very suitable for comparison. The line 4554.4 is the strongest in the barium spectrum, and the line 4533.5 is one of medium importance in the radium spectrum.

When the purification was stopped, the strongest barium line was still faintly visible near the other. Its complete elimination seemed to be very difficult with the quantity of material I had at my disposal. Nevertheless, I shall shortly show that the salt was very pure.

I was confronted with one difficulty during this work. When a clear solution of a radium salt is evaporated in a dish or glass, the dry sale obtained is not generally completely soluble in water, but leaves a residue. I have found that this residue is partly due to the formation of radium sulphate, in consequence of the presence of traces of sulphuric acid in the reagents (traces which could only be detected by barium salts after the concentration of the reagents), and partly to the slow action of the radium salts on the vessels. I therefore decided to prepare specially all the reagents employed. The water was distilled in a platinum still, and received and kept in a platinum flask; this water was used to prepare the hydrochloric acid, which was also kept in

*Comptes Rendus, 1907.

a platinum flask. The nitric acid, alcohol, and silver nitrate were also purified. It is not possible to let the radium chloride crystallize in presence of hydrochloric acid in a platinum dish, because it has considerable action on the latter. But if the clear solution is allowed to crystallize rapidly in a porcelain dish, crystals are obtained, which, after being dried, dissolve in the purified water without residue, and hence can be used to determine the atomic weight.

The method employed for this determination was the same as before. It consists in estimating as silver chloride the chloride contained in a known weight of anhydrous radium chloride. According to my earlier experiments, which were confirmed by new observations, radium chloride, which has just been prepared, loses its water of crystallization when it is heated in a drying oven above 100 deg. C., and its weight is quite constant when it has been subjected for half an hour to a temperature of 150 deg. C.

The weighings were performed with a Curie's aperiodic balance with direct reading for weights below decigrammes. This rapid balance is accurate to one-tenth of a milligramme, and takes only seconds to reach its position of equilibrium. The weighing of the radium chloride is more difficult than that of the silver chloride, because the former salt absorbs water vapor rather quickly; it is therefore essential to let it cool in a dessicator with phosphoric anhydride before weighing, and not to recommence weighing until after it has been again placed in the drying oven, even if the cage of the balance contains desiccating substances.

After each estimation the radium is present as nitrate with silver nitrate. The silver is eliminated by hydrochloric acid, and the nitric acid by repeated crystallization in presence of hydrochloric acid.

The following table gives the numbers obtained in three consecutive experiments, and the atomic weights P deduced from them, assuming that radium is a divalent metal, and that the atomic weights of silver and chlorine are:

Ag=107.8, Cl=35.4.

| Radium Chloride. | Silver Chloride. | P. |
|---|---|---|
| 0.4052 | 0.3906—0.00006 | 226.35 |
| 0.4020 | 0.3879—0.00006 | 226.04 |
| 0.39335 | 0.3795—0.00006 | 226.15 |

Weight of filter ash=0.00006

The weighings of the two chlorides are considered to be exact to about one-tenth milligramme. These three experiments, which agree very closely, give for the atomic weight of radium the mean value 226.18.

The experiments, performed in 1902 with very pure radium chloride, gave less concordant results and a mean of 225. The spectrum of the salt used recently shows a rather greater degree of purity, but the difference of about one unit in the atomic weight could not be ascribed to this cause. I performed a control experiment as follows: I prepared a solution of some milligrammes of pure 1907 salt, and added to it a small quantity of a titrated solution of barium chloride. The amount of barium salt in the mixture was 0.61 per cent. In the spectrum of this salt a great increase of the intensity of the barium spectrum is shown, whereas the change of atomic weight, calculated from the known addition of barium chloride, is only 0.7 unit. From the examination of the spectra it is clear that the difference between the numbers obtained in 1902 and 1907 should be attributed only to the inferior accuracy of the experiments performed with only 9 centigrammes of radium salt and with less pure reagents.

The above experiment also proves that the spectral reaction of barium in presence of radium is very sensitive and that the radium chloride which was used for the determination must be very pure. It certainly does not contain 0.1 per cent of barium chloride.

I therefore conclude from these experiments that the atomic weight of radium is 226 2 (Ag=107.8, Cl=35.4) with a probable error of less than half a unit.

If the values Ag=107.93, Cl=35.45 are adopted, the value is Ra=226.45.

## WHAT AND HOW MUCH IN HIGH SCHOOL CHEMISTRY.

By Fredus N. Peters,

*Central High School, Kansas City, Mo.*

No science, perhaps, occupies a broader field than does that of chemistry. The man who has spent years of investigation in this line of work and who is able, therefore, to hold within his mind's eye a paoramic view of a large part of the field, sees so much of wonderful interest and fascinating beauty that he is at a loss to know just what portion to explore with a class of beginners.

Before he can do much toward attempting a solution of the problem before him he must decide something as to the purpose of the school in which he is engaged. The high school, for example, has often been referred to as "the people's college"; by many universities, however, it is regarded solely as a means of preparing students for entrance to their courses.

If we accept as true the statistics of our school men who have studied the matter we learn that from 25 to 50 per cent of the high school graduates enter college. Some schools may occasionally send a higher percentage than this, but such is not the case over the country as a rule. Even 20 per cent, however, when we consider the probable character of that number, would deserve consideration; and if a reasonable portion of that number need chemistry for college entrance or will be materially benefited by a good high school course in chemistry, as teachers of that subject we should carefully consider the matter.

On the other hand the large portion of our students close their school days when they receive their high school diploma. This large majority therefore also demands earnest consideration.

Now it must be conceded that there are many things of value to the student who expects to continue the subject, which might well be neglected by those who will take only the first year. For example, the prospective college student may well be looking toward much of the theory which is full of charming interest, and toward analytical chemistry; and the experimental part especially, of his first year work should keep these objects in view.

The general student, on the other hand, might omit such experiments as lead to qualitative analysis and much of the theo-

[1] Read before the Physics and Chemistry Section of the Central Association of Science and Mathematics Teachers, in St. Louis, November 30, 1907.

retical, and emphasize that part of the science which deals with the practical applications to everyday life.

Granted that such a flexible course as this is desirable, is it possible to carry it out in practice? Without having attempted it, possibly I may be pardoned for theorizing upon a subject which as far as I know has never been tried by anyone. It is probable that in all the smaller high schools the number preparing for college would be so small that it would be impossible to give them a course in chemistry especially adapted to their future work. In the larger high schools with 100 to 150 taking chemistry there would probably be a sufficient number of college preparatory students to form one good class in chemistry; but judging from my own experience, it would be nearly impossible to get all these together into any one hour of the day. Assuming this as possible, however, would it be worth while attempting it? I confess I do not know and should like the opinion of others. It depends, so it seems to me, very largely upon the university man to whom the student shall go for his first college work in chemistry. If he is to be put into a class, most of whom have never been exposed to chemistry, and be compelled to do again even a considerable portion of what he did in the high school (and this will of necessity be if he has had a good stiff course in the high school) it is altogether probable that he will never become an enthusiastic student in chemistry, for very few really enjoy marking time very long.

It is probable, therefore, that we shall be compelled to offer a compromise course in high school chemistry—a course suited largely to the student who will have but the one year and yet with sufficient of the theoretical and analytical that the prospective college student may be prepared to carry freshman chemistry which presupposes some knowledge of the subject.

With this much settled or assumed as settled, the greater task is still before us. As already stated, the field is so enticing that it is a serious question what shall be included, and what omitted. For years there has been a tendency to add more and more. First came the addition of the laboratory course, now recognized as a necessity; then to this which has been almost entirely qualitative there was added a greater or less number of quantitative experiments; then came the development of several new theories, various new manufacturing processes, and within the last two or three years a demand for a considerable amount of organic work, including the paraffins, their hologen derivatives, acids, alde-

hydes, alcohols, and ethers; the olefins, including a long list of acids more or less closely related—lactic, malic, oxalic, tartaric, citric, etc., and their salts; the glycerins, their ethers, fats, oils and soap; the saccharids, including the sucroses, glucoses, amyloses; dextrin, and cellulose; benzene and its derivatives, phenol, aniline, nitrobenzene, picric acid, acid and aldehyde derivatives, and the homologues of benzene, toluene, cinnimene, naphthalene, anthracene, alizarin, and purpurin; the terpenes, turpentine, camphor, nicotine, caffeine, cocaine opium, cinchona, strychnine, pyradine, and many others of which these are but samples. I also find in some of the newer books a chapter on animal or physiological chemistry with a study of digestion, fermentation, the blood, casein, albumen, the gelatins, etc. *And this is not all;* when the student has accomplished all this, there is still time for a pretty good course in qualitative analysis, and all within the usual nine or ten months of the high school year!! I know a lady in our city who told me her son, who was preparing for one of our great Eastern universities, had done five years' work in modern and ancient languages, most of which he was taking for the first time, besides the usual amount of English and mathematics, all within the space of ten months. At our high school this same boy was with difficulty induced to make 12 yearly points in three years' time. The ability of some teachers to stimulate their students is surprising. I have longed for it; I have sighed for it; I have almost prayed for it, but it has never come, and I have concluded such teachers are born and not made. I am trying as hard as possible to forget that this is true; for, realizing my utter inability to accomplish such results I am forced to the conclusion that I am fast becoming a back number, and will soon be laid upon the shelf to await the resurrection day of those chemists who have been tried and found wanting.

Gentlemen, I believe in doing well what we do. I would much prefer to spend seven or eight months upon the non-metallic elements, with the theories and quantitative experiments which naturally find a place there, and teach that WELL, than to spend four months there, three or four upon the metals, and the balance of the year upon organic compounds and qualitative analysis. With such an intensive course, I believe the student would be vastly better prepared to pursue his work in college with credit to the school from which he comes and with some assurance of success. Let us quit spreading out, and put a little thicker cov-

ering on what we do. Let us settle upon some things as essentials and urge every one to do these thoroughly.

To decide what are essentials, however, is easier said than done. Ten years ago, I am sure I knew exactly what should be taught and just how to teach it. To-day I fear I have lost some of that serene assurance and am sincerely longing for some Moses with divine inspiration to lead us to a land of promise. We are agreed, however, I think, that a certain amount of quantitative work must be required. As chemistry never became a science till the balance was applied to the verification of its truths, so the student never learns accuracy of manipulation, nor appreciates the care necessary for success till he has done considerable quantitative work. In our laboratory, if you will pardon the reference, we have for several years required the following, with more or less variation from year to year.

Amount of water of combination in magnesium sulphate, alum, etc.

**Per cent of Oxygen in Potassium Chlorate.**
**Weight of a Liter of Oxygen.**
**Displacing Power (Equivalent of Fe, Al, Mg, Zn).**
**Recovery of $MnO_2$ and Potassium Chloride in Oxygen Work.**
**Preparation of Acid and Normal Salts.**
**Per cent of Carbon Dioxide in Carbonates.**
**Weight of a Liter of Carbon Dioxide.**
**Law of Definite Proportions (Two methods).**
**Equivalent (Combining Weight) of Copper.**
**Titration of Acids and Alkalies.**
**Molecular Weight of Sulphur Dioxide.**
**Equivalent of Zinc (Combining Weight).**
**Equivalent of Lead (Combining Weight).**
**Estimation of Iron with Potassium Permanganate.**

This gives about fifteen quantitative experiments, besides a few, such as the electrolysis of water and the synthesis of it by the eudiometer, and with hydrogen passed over Copper oxide, made in the lecture room by the instructor. If I may judge from some texts others may attempt in some cases more than this. Whether this is enough I am not prepared to say. However, as a rule it has seemed to me that students really enjoy those experiments which demand an accuracy and nicety of manipulation better than most anything else of their first year work. It is true that such as are inclined to be careless in their weighings, and whose results, therefore, are so far wrong as to necessitate a repetition, do not like quantitative work; but we are not to base

our conclusions of its value upon anything they may say. At first students who have not had physics are worried more or less by the application of Boyle's and Charles's Laws, aqueous tension and the like in correcting gas volumes, but it is not long until they are able to handle these problems intelligently and with pleasure.

EQUATIONS NOT THEORETICAL.—I believe it is important also after the idea of the equation has been developed that some work should be done to fix firmly upon the mind of the student the fact that equations are experimental and not theoretical. Exercise what care I may, use every precaution possible, I still find a strong tendency among students to want to "work out" on paper the equation, regardless of what their experiment has revealed. We have not done as much of this, I believe, as we should; yet it would be a very easy matter to arrange a series of simple experiments keeping this object in view, and I am not sure but that it would be worth while. Beginning with the simplest or those most self evident to the student we have used the following for this purpose.

**Electrolysis of Water.**
**Synthesis of Water by Copper Oxide and Hydrogen.**
**Decomposition of Water by Sodium.**
**Decomposition of Sulphuric Acid by Zinc.**
**Preparation of Oxygen from Potassium Chlorate.**
**Preparation of Nitrous Oxide.**
**Decomposition of heavy Metallic Nitrates.**
**Preparation of Chlorine from Salt.**

In some of the above we have not used methods that would satisfy in every particular the nice discrimination of the skilled chemist, but as a rule the course pursued is sufficiently accurate for the beginner and serves to assist in impressing the fact, with the aid of the instructor holding a sledge hammer over the student, that equations are really the outgrowth of quantitative experiment.

IMPORTANT THEORY.—There are some theories which it seems to me must not only be studied in the class room, but emphasized also in the laboratory. Among them I would mention:

**Ionization.**
**Mass Action.**
**Reversible Equations.**
**Hydrolysis.**
**Natural Grouping of Elements.**

A large number of experiments occurring from time to time may be used to illustrate the first of the above. It is my experience, however, that with conscientious endeavor both in the lecture room with a variety of experiment there, and equally persevering attempts in the laboratory to teach this theory and some of its beautiful applications, the results have been far from satisfactory; and it is my firm belief that comparatively few of the photographic plates exposed to this treatment and those only the most sensitive show any clear prints when the final test comes. Whether the attempt should be abandoned with the mixed classes we have and leave it for the prospective college student to get when he may later, I am not attempting to say.

MASS ACTION AND REVERSIBLE EQUATIONS:—These naturally go together, and a variety of simple experiments may be used to illustrate. For example, the precipitation of zinc as Sulphide from zinc acetate and from zinc sulphate, the latter with varying amounts of sulphuric acid added to the original solution before precipitation begins; (2) The conversion of antimony chloride into the oxychloride and the reverse; (3) The conversion of bismuth nitrate into the subnitrate and reverse. These and others of similar nature are interesting experiments and are not only enjoyed but understood by the majority of the students.

Hydrolysis cannot well be omitted. The student finds aluminum precipitating as hydroxide by the use of either a carbonate or sulphide. He studies tre chemical action of alum in baking powders; he sees the action of sodium carbonate upon ferric chloride, the preparation of basic lead carbonate when sodium carbonate is added to the solution of a lead salt, and various others. These are but examples of many experiments of this character which demand explanation. With the student on his guard, working slowly and watching carefully for results he will see and understand something of the many applications of this principle. For a real appreciation of it, however, he must know something of the ionic theory.

A number of experiments may be used to illustrate some of the facts brought out in the periodic table. If we study the oxides of zinc, aluminum, arsenic, and sulphur, as to their acidic and basic properties, we learn not only the fact of increasing acidity from left to right, but also the double character sustained by various elements occupying positions near the center of the table. If we

study the oxides of the elements of the nitrogen group, we learn experimentally the decreasing acidity of them as their atomic weights increase; so in various other experiments which we really perform we may make applications bearing on the facts set forth in the table.

In mentioning the above I have given the experimental side only, but I have left you to infer that all this is supplemented strongly in the lecture room either by repetition of some of the experiments, the addition of others, or in such other ways as necessity seems to demand.

LAWS.—In preparing for this occasion I have taken time to look over again some of the elementary texts now before the public, and I find the following laws discussed at greater or less length in some or all of them:

**Conservation of Matter.**
**Constant Proportions.**
**Boyle's.**
**Charles's.**
**Avogadro's Hypothesis.**
**Osmosis.**
**Definite Proportions.**
**Multiple Proportions.**
**Dulong and Petit's Law, and possibly some others.**

Whether we can serve up this entire bill of fare without bringing about many cases of serious mental gastritis, I am not sure. I have never felt that I was equal to the task, hence have emphasized strongly by experiment and class study only about half of them. I am not saying anything, however, about what others can do—I only know my own limitations.

Thus far in giving the content of the high school chemical course I have mentioned largely those phases which I presume will be most necessary in preparing the student who expects to continue the subject in college. The other portion—the majority—under present conditions will be compelled to take this dose, as well as those who want it or must have it; we must make strong effort therefore to present it in such a way that it will be as little objectionable as possible. In fact, I believe a good deal of it may be largely sugar-coated and yet be fairly efficacious for all. More than this we must provide for the general student equally well. This must come, it seems to me, through the practical phases of the subject. These are not only many but interesting. Among them I would mention:

**Refrigeration.**
**Explosives.**
**Bleaching cloth, feathers, fruits, silks, and straws.**
**Illuminating gases; coal, acetylene, water and pintsch.**
**Glass and its varieties.**
**Matches.**
**Soaps.**
**Cement work and plaster.**
**Softening of hard water.**
**Clarifying sugar.**
**Simple photography.**
**Electro-plating.**
**Baking powder and Soda biscuits.**
**Clarifying city water supplies.**
**Galvanized Iron and Tin.**
**Type-metal, shot, solder.**
**White lead, Chrome yellow, Paris green, etc.**
**Pig iron and Steel.**

To enumerate this seems like a formidable array, yet it may be classified and accomplished with much greater ease than would seem possible.

Another suggestion I make in behalf of the general student. We have found among our classes a very great interest taken in the preparation and purification of various compounds, for example, those of potassium from wood ashes. This is work which comes up naturally during the last third of the year or after we begin the study of the metals. If the students are encouraged to preserve specimens of what they prepare, and are required to know what they are doing, they not only become wonderfully interested in the work, but are greatly benefited as well.

Before closing there is one other matter I wish to suggest, and it is one I have thought over for some time. Would it be possible, or if possible would it be advisable at the end of the first half year in chemistry to divide the classes in such a way that those who are preparing for college and the stronger students might be put together and given a good stiff course the remainder of the year; the other division to be offered a course in applied or domestic chemistry, taking up considerable more in detail than we do now the practical phases of the subject? In some ways the plan appeals to me. For example, some three years ago, in our study of bread and biscuits, I suggested the plan of using soda and hydrochloric acid as a leavening power instead of ordinary baking powder. Not only were the girls much interested, but the boys as well. In many instances where they could not induce

their mothers or the domestics at home to make the experiment, they went into the kitchen and did the work themselves, both boys and girls. For three weeks we had brought in before school every morning not only biscuits, but muffin and layer cakes, showing many very excellent results. I kept a tabulated report of each case, noting kind of flour used, shortening, whether mixed with milk or water, and such other data as I thought might be of interest or value in judging of the results. Such a course would mean an immense amount of work for the instructor, as it would almost have to be constructed from the ground up. Still it might pay.

The time allotted me is too short to present this subject in any way other than fragmentary and suggestive. What I have said has been offered with the hope that it may lead to a general discussion before this body and result in some conclusions to which we may hold fast. There are some things in connection with the teaching of chemistry regarding which I have firm convictions; there are others of which I do not feel sure. May we take counsel together and in the end find much that will be helpful to us through all time.

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## ELECTRIC SPARK PRODUCED WHEN ICE IS FORMED.

**Dr. T. L. Phipson, in his book "Phosphorescence," London, 1862, page 29, publishes the following suggestive paragraph:**

**A most interesting production of light was observed and published ("Journ. des Sc. Physiques et Chimiques," de M. de Fontenelle) by Professor Pontus, in 1833, who showed that a vivid spark is produced when water is made to freeze rapidly. A small glass globe, terminating in a short tube, is filled with water, the whole is covered with a sponge or cotton-wool imbibed with ether, and placed in an air-pump. As soon as the experimenter begins to produce a vacuum, the ether evaporates, and the sponge or cotton-wool dries, the temperature of the water descends rapidly. But some instants before congelation takes place, a *brilliant spark, perfectly visible in the daytime*, is suddenly shot out of the little tube that terminates the glass globe. M. Pontus has repeated the experiment often, and says that the production of this spark is a sure sign that congelation is about to happen.**

**The Editor has not been able to obtain the original memoir by Professor Pontus, but if there be no mistake in this experiment and observation then we have here a very plausible explanation of the origin of the lightning that attends hail and thunderstorms in the summer and equally so of the gentler electric discharges attending thunderstorms in winter—possibly also of the still gentler auroral discharge. Will not someone investigate this subject anew?—*C. A., in Monthly Weather Review, July, 1907, page 317.***

# AN APPRECIATION OF THE PEDAGOGICAL POSSIBILITIES OF THE BIOLOGICAL LABORATORY.*

By T. W. Galloway,

*James Millikin University, Decatur, Ill.*

The belief is growing upon us that our whole scheme of education is to be considered as a huge experiment in which we are just beginning to evaluate some of the variables. It is, to be sure, the most important experiment ever undertaken in the history of the race. The more optimistic, or the less discriminating, speak of a *science* of education. The most we can now say, however, is that education is a subject open to scientific treatment. The growing recognition of this truth guarantees and makes necessary to us the right of continuous appeal, and of a re-appraisal of educational methods.

I do not believe that the method of using the biological sciences as a means of education has received the attention which it should have had from our best students of biology. The subject-matter of biology is so abundant and attractive, and the new fields of investigation so insistent in their demands, that our biologists have not taken time to assimilate the material from the viewpoint of teaching, nor to formulate the purposes and methods most appropriate to it as an instrument of education. We have allowed too much of the pedagogical literature of the subject to be written by the theorist whose knowledge of the subject-matter is superficial. There is no department of investigation which has, as a matter of fact, made such foundational contributions to the general methods of pedagogy as has biology. No statement of the purposes of education has ever been made which is so satisfactory as that which describes it as intended to secure the ability to make right response to all kinds of stimuli; in a word, *adaptation to all the vital realities.* This is fundamentally a biological conception, and identifies education with life. A science so close to the foundations of pedagogy as biology is should not allow any opportunity to pass which may in turn secure to it its rightful place in the great educational experiment.

In spite of the seeming indifference of the great majority of

*Read before the Biology Section of the Central Association of Science a Mathemat ics Teachers, St. Louis, Nov. 29, 1907.

our leading biologists to the pedagogy of the subject, there have been noteworthy gains in the last half-century. Particularly in the last fifteen years has there been a series of text-books in both Botany and Zoölogy which try to respect the nature of the teaching process, as conditioned by the pupil, quite as much as the matter of the subject.

The first noteworthy gains in the method of presenting natural history subjects are scarcely beyond the memory of the present generation. Chief among these is, of course, the introduction of the laboratory method in the school—the study of the object instead of book-descriptions of the object. This is properly recognized everywhere as one of the most radical and significant pedagogical advances ever made. The spirit of it has invaded every department of investigation, and with uniform advantage to the investigation. It has come to stay. Its purpose is to make every piece of study an original investigation. It means, at its best, the stimulation of individual initiative and discovery, rather than individual acquiescence.

In the early stages of the laboratory development there were two things which appealed strongly to the experimenters. The first was the stress to be put on *individuality*. All results were to be the students' very own. This led to the method usually attributed to Agassiz. It consisted, briefly, in turning the student into the materials and telling him to go to work. He was expected to develop both his problems and his solutions. As an occasional device—as a kind of corrective to the opposite tendency in teaching—this method has been very valuable. But as a general laboratory method, for the average laboratory, it is wasteful both of time and of men. It is too severely selective to be generally useful.

The second strong appeal made by the new device was the opportunity to secure *observation* of facts at first hand, and thus develop a power—fast undergoing atrophy in our general students, who had long been dependent upon books for their materials of thought. Through imperceptible stages this motive of observation came to dominate the laboratory and the notions of the purpose of the laboratory, until the element of individuality was buried in it. Individual work came to mean merely observing facts. This condition found its culmination in the laboratory manuals of Huxley and his followers. In these the directions were so complete that the student's work became merely one of

verification, with the incidental hope that the attractiveness of the subject-matter might arouse an individual enthusiasm which the mere process could not possibly do.

It was after a period of 15 or 20 years of this sort of work that the enemies and friends of the laboratory alike were brought to ask whether or not the laboratory, after all, had justified its early promises as an educational device.

Not a few were disposed to answer with a clear negative, and I am disposed to agree. Without taking time to follow the development of the laboratory from then till now, it may suffice to say that this was the vitally critical moment in the history of the laboratory method. The improvement growing out of the attempt to answer this question has made the general laboratory of to-day, in the hands at least of the best teachers, infinitely better than that of 15 years ago. The best teachers are in practical agreement, I think, that the following counts in the indictment of the laboratory are sustained by the facts:

1. The observation-fetish has been decidedly overworked. From the point-of-view of acquisition, it makes no real difference whether a fact is obtained through observation or by authority, if it be equally thoroughly acquired. There are no intrinsic merits in "observed" facts, unless they contribute to the *individuality* of the observer. It is individual power and not mere observation for which the laboratory stands.

2. Much time is lost in getting facts in this way. It is the least economical mode of getting facts, indeed. Life is too short to force the individual determination of all necessary facts. Education must be an *epitomized recapitulation* of racial discoveries; not a *duplication* of them.

3. The laboratory will no more run itself than a class-room will. On the whole, unguided, or unrelated, or illogical work in the laboratory is worse pedagogically, than the old text-book method. More time is wasted, and there is less real inspiration in it, to the average student, than in a good text-book.

4. The average laboratory stops short of its vital possibilities, because of the stress that has been put on mere observation. In the effort to get the student to observe, and to record his own observations rather than those of other people, the fact has been lost sight of, in practice at least, that the power of observation is not the chief end of man nor the whole of personality to which the laboratory may contribute.

Constructively I think there must come to be essential agreement as to the following principles, if we are to make the laboratory really fill its possible place in the educational scheme:

1. The teacher must be in the closest possible touch with the work at every stage; not to dominate it, but to see that time is not unduly wasted, and that it does not run amuck. This means the teacher and not some inexperienced and immature substitute who doesn't recognize the place of the laboratory.

2. The guidance must be such as to leave every possible incentive to the student. The work must be his. The great work of the teacher is to multiply incentives; to assist nature in arousing problems and questions; *not* to arrest interest and development by answering them. Practically, in order to preserve individual effort and interest, and yet save time, the analysis of the work expected should be carefully made, but should take the form of questions, rather than statements of truth; questions which do not answer themselves. It is remarkable how quickly this simple device will convert the student into the original investigator. This result cannot come from the laboratory guide of the Huxley type, nor from the modern detailed outline based upon it, which is still found in many of our laboratories. The laboratory guidance must be much more plastic and adjustable to the state of mind of the individual student than can be true of such, if it is to secure his mental development.

3. Pedagogically we should *"follow through"* in the laboratory. It appears to me that this is the point at which we have most signally failed to realize the full educational value of the laboratory. I have been associated, as a student, with some of the best laboratories of the country, and I can see now that those laboratories were radically defective in getting, in me, the final intellectual results which should have come from the work which they gave, and I do not think the fault was mine. The work actually done was good; but it was vitiated by the fact that the student came to feel that the laboratory had done its best work for him when he had made accurate observation of the available facts and an accurate record of those facts. This was partly due to the ascendency of morphology fifteen or twenty years ago, and partly to the age-old fallacy that education is primarily a gathering of facts.

Because observation is initial and thus a basal step in the laboratory method, our teachers have been slow to realize that there is

no discipline at the command of the teacher so effective as the biological laboratory in training in comparison, discrimination, in classification, in inference and controlled generalization. This failure not merely robs the student of what should really be the culmination of his training, but it has brought the whole scientific process, as a means of education, into some disrepute in the minds of educational experts.

By "following through" I mean that the student should be caused to realize that his work is not done until he has made all the inferences which are legitimately to be derived from his observations, and has put his results in the form of *statements of truth,* subject, of course, to further correction or verification by renewed observation. I believe further that the student should be aroused to a consciousness of his mental states; he should become interested in the working of his own mind in the laboratory processes; he should know when he is stating an observation, and when he is making an inference; and should be able sharply to separate his observations from his inferences. I believe that the teacher should select his exercises quite as much with reference to securing the utmost mental activity and the surest mental response, as for the purpose of furnishing a complete illustration of the animal or vegetable kingdom. I believe that personality is stultified whenever it is not allowed to make the normal series of reactions legitimate to the conditions; and I think the average laboratory habitually stops short of these normal conclusions. I take it that the laboratory method, *and every exercise in it,* should look toward an order of mental activities something as follows:

1. Careful observation and statement of facts.
2. A comparison of these *facts.*
3. Discrimination between facts; distinguishing the essential from the incidental.
4. Comparison of *objects,* based on the interpretation of the facts.
5. Classification of *objects.*
6. Generalization, or statement of *principles* or *truth,* as inferred from the preceding work.
7. Re-testing conclusions by re-applying them to a broader field of observed facts.

The process is from *facts* to *objects,* and from *objects* to *principles.*

I do not hold that it is necessary for the student to take each of these steps with a conscious stop and inventory of results after each; but I know it is well for the director of the laboratory to find whether these steps are being taken by his pupils; and I am thoroughly convinced that the knowledge of the fact that he should follow something of this order in reaching sane conclusions is beneficial to every student. It gives him an interest in his own mental processes which is of more value to him than any amount of biology pure and simple.

As I remember my own laboratory work as a student, the whole attention, practically, was given to securing close observation and reasonably accurate statement of results. The work was pretty nearly a dead loss so far as any further utilization of the facts was concerned. The facts were left to bring forth what fruit they might. I believe nine-tenths of the value of the average laboratory is lost because the director is not planning to secure the later steps of the scientific method.

In order to make concrete what I have been saying, I shall give, in some detail, one of the first exercises which I use in my laboratory, with beginners in biology. As nearly as circumstances will allow I try to secure similar modes of activity in all laboratory and field work. As soon as the students have become familiar with the use of the microscope I give each of them, under the heading *"Forms of Matter,"* some fine sand, some pebbles. crystals, infusorial earth, shells, plants and animals in succession. Beginning with the sand I ask the pupils to enumerate every fact that they can observe with respect to the grains, with and without the microscope. They are allowed to use any real personal observations they have ever made. I insist upon careful, unexceptional statements of observations in writing. The statements must be broad enough to include all the grains given the student. I insist that each observation shall be as simple as possible, and that it shall not be an *inference* based upon their real observations or general knowledge. I hold them strictly to what they can get with the facilities at their command. I lead them to undertake to determine just what senses are involved in each statement of observed fact; and gradually to realize that they are observing only qualities of the thing, and not the thing itself.

They get in this way a list of characteristics of sand-grains as they see them. Before passing to the pebbles I ask the class to look over their lists and see whether they can put their character-

istics in better *order* than that in which they first put them down. In this way I cause them to develop an order of treatment which represents their best appreciation of the relation of the qualities. This list will likely include items of form, size, surface, color, transparency, hardness, and other items depending upon the care and quickness of the pupils. At certain stages I resort to the general quiz and allow various members to contribute to the total result. We use with the later objects studied the order and general categories developed for the sand, with whatever added ones may be necessary.

Similarly, lists of characteristics are found, observed craracters I mean, ior the other objects. Naturally the students institute comparisons with the objects already studied, but I insist upon a statement of the observed facts concerning each object independently. By the time these lists of qualities are enumerated I have a pretty good line on the powers of observation and expression of the members of the class.

During our progress I have, by questions, if they have not recognized it independently, developed the fact of a kind of *individuality* in the crystal, because of its definiteness of form, which was not found in the grain of sand or the pebbles. They readily recognize that a broken pebble is two smaller pebbles, but that a broken crystal is not two crystals.

From the study of the shells and infusorial earth they get the *fact* which, later, we express by the terms differentiation and organization—a quality not shown by the preceding objects.

I allow, in the case of the plants and animals, any real observations the pupils have made, of any plant or animal, anywhere. I only insist on a record of those qualities belonging to the plants and animals known to him, or which I can introduce in the laboratory at the time.

When these lists are as complete as the student can make them, I have each student take the qualities of sand, as he has discovered and enumerated them, and check those features which he regards as the most *important;* those qualities which are really essential to it, *as sand.* A little quizzing will bring out the fact, for example, that color is not an essential, because the grains show practically limitless shades of color under the microscope: and that size is, because, if we consider it increased or decreased indefinitely, the material would cease to be sand. Similarly with the other objects. I regard this a vitally important exercise; be-

cause I think the power of discrimination between essential and incidental qualities at once the most important in life, and the most difficult of attainment. Our educational devices fail more signally at this point, in my opinion, than anywhere else in the whole program.

We discuss with the utmost openness and thoroughness the grounds for considering this or that feature as vital. The promptness with which the students enter upon this, shows its acceptability. When the class is satisfied that it has the really vital matters indicated, I ask them if they were to read their essential qualities to some one coming into the room for the first time, whether that person would be able to recognize what was under discussion. This question usually brings out one or more items which seem fundamental and diagnostic qualities of the object.

I next ask for a comparison of these objects on the basis of the qualities which have been enumerated for each. I ask that the characters which distinguish the grain of sand from the pebble or the crystal or the shell, be noted in some way; and that those features which seem to ally or bind together certain of the objects be indicated. After this much of comparison the student is required to take the list of seven objects, and group them into whatever groupings he deems most satisfactory on the basis of his conception of the value and importance of the respective points of similarity and dissimilarity.

During this exercise the fundamentals of classification are gradually brought to the consciousness of the pupil. Even from a simple exercise like this the pupil can be made to realize the propriety of using the more fundamental qualities for the first cleavage of objects; he can appreciate the necessity of using one basis of classification, only, at each step; he can appreciate the simplicity and effectiveness of the "dichotomous" divisions in classification.

We continue this analytic classification until each type of object stands in a group to itself, separated from the others by purely observed features of the pupil's own discovering. Of course, I do not allow a classification based on a complex notion like *"living"* and *"non-living,"* as most students want to make at once. It is only necessary to ask whether he has really *observed* life, or whether he has inferred it from some simpler facts which he has observed.

After this analysis has been made the student has a diagram something like this:

| | | | | |
|---|---|---|---|---|
| "FORMS OF MATTER" | NOT ORGANIZED | FORM INDEFINITE | Size small (limits)—Sand | |
| | | | Size larger (limits)—Pebbles | |
| | | FORM DEFINITE | ——————— | CRYSTALS |
| | ORGANIZED, (or differentiated into special regions) | Destitute of power of reproduction | Difference in size and details of structure | Infusorial Earth |
| | | | | Shells |
| | | Reproduction and certain other modes of activity | Motion not striking | Plants |
| | | | Motion pronounced | Animals |

With just a little questioning the student can be made to see that his classification is, itself, a kind of definition of various types of objects. It involves a general statement. I now ask him to write out in a formal and critical way any general *conclusions, not observations,* but *inferences,* which he feels he can afford to make on the basis of the work he has already done. I find that this exercise is an excellent opportunity to point out the unsafety of making sweeping generalizations, and the necessity of checking general conclusions sharply by the real known facts.

Teachers will realize that, in addition to the drill in the meaning and order of the scientific method, I am trying to give the pupils an empirical ground for distinguishing between what we may call amorphous matter (such as sand and pebbles); other inorganic matter, such as the crystal, which is individualized in form, but lacks the organization and differentiation seen in shells and in plants and animals; matter which is not alive, but is organized because of its association with living objects, as the shells and infusorial earth; and finally objects which we call living. We are not, of course, after a scientifically exhaustive list of distinctions, but after *working-distinctions* for elementary pupils.

When these categories become satisfactorily developed, through suggestive questions, I ask the student to try to suggest other objects which I might have used in each category to have illustrated the same truths. I ask him to suggest some object which might have been studied that will not fall in any of these groups. The doing of this tests and extends the generalizations, or corrects them so as to make them apply to new facts. I insist at this point that the scientific man holds all his opinions and conclusions subject to correction in just such way.

The sanity of this kind of an appeal to the intelligence and confidence of the pupil has been proved to me over and over by the promptness and the fullness of the response which almost

every pupil makes to it. It takes much more time than the conventional laboratory work; we cannot cover as much ground as we could with an outline constructed on the Hûxley type; we do not, perhaps, get as many facts as are gained when only facts are sought; but we do get a knowledge of mental processes, a sanity and poise, an attitude of interpretation and "following through," a willingness to reconsider, a disposition to question what is and what is not essential, which, to my mind, are to be considered the finished product of the laboratory method as an educational device.

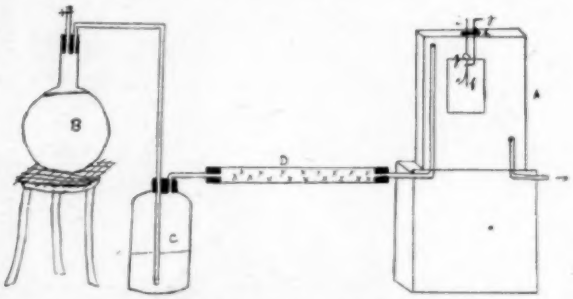
I desire to add, in conclusion, that one of the results of this mode of using the laboratory (and this is not the least of its merits) is the enforced attention to physiology and to ecology. None of the aspects of Biology lend themselves so completely to this broader treatment as do the studies in the field. No approach to morphology so vitalizes it as this enforced search for the *meanings* of form. It secures and enforces a balance between morphology and physiology and ecology which is much to be desired. It tends to make the study of morphology less a matter of statics than of kinetics. Finally, the principles invoked in this illustration are not confined to synthetic and inductive work; there is scarcely any field of human study which offers better possibilities than the laboratory for analytic and deductive exercises. Lack of time, however, forbids that we should undertake to develop this aspect of the question. It is the deliberate conviction of the writer that it is yet open to the biological laboratory to make great contributions to the processes of education, by insisting on the simple proposition that each stimulus presented to the student, whether in the form of an object or of a relation or of an activity or of a problem for analysis, shall be allowed, under expert guidance, to produce its *normal and consciously finished reaction in the personality of the pupil, and not be interrupted by any artificial standard of purpose erected by us.*

## APPARATUS FOR SHOWING THE RADIOACTIVITY OF WELL AND SPRING WATERS.

By Blancha L. Daniels,
*Mount Holyoke College.*

A comparatively simple method can be used for showing the radioactivity of natural waters. Almost any laboratory has the material for setting up the following apparatus.

The gold leaf electroscope, A, which is of the C. T. R. Wilson type[1] can be made from a tin cocoa box. *e* is a small gold leaf




1 cmx1.5 mm; *f* a flattened piece of copper wire 2 cmx2 mm; *g*, a sulphur bead for insulation and for holding *f* to the wire *i*; *j* is a copper wire bent at two right angles, used as a charging device; *h* is an ebonite stopper. Small mica windows are attached to each side of the case to permit viewing the gold leaf. Inlet and outlet tubes, preferably of metal, are provided, and the whole instrument made as air-tight as possible by sealing wax. The leaf can be charged inductively by means of a charged glass rod; while the rod is held near the top of the electroscope, move the bent wire, *j*, until it touches the gold leaf support, *f*, and then move it aside again. The case should be connected to the earth and the top of the electroscope shielded by a cap of metal foil.

A boiler, B, of several liters capacity, is desirable, although a liter flask will do if the water is rather radioactive. C is a condensing bottle containing cold water; D, a drying tube of fused calcium chloride. The boiler should not be completely filled, enough room must be left for the expansion of the water. There must be room also in the jar, C, for the condensed steam.

The electroscope should be charged and the rate of discharge noted for ordinary dry air. This can best be done by using a

[1] Rutherford, Radioactivity, p. 86.

reading microscope provided with a scale in the eye piece. When this rate has been determined, find the rate after the gas from the boiling water has forced itself through the apparatus for about half an hour. If the water is active to any considerable extent, a much greater rate will be noticed. In case a reading microscope is not available it might be well to cast a shadow of the gold leaf upon a scale. In cases where the water is rather active no device for reading the rate of the fall of the gold leaf will be necessary; the time taken for the leaf to be completely discharged in an atmosphere of dry air may be noted, which ought to be several hours, and the time for its complete discharge in the gas, which may be only a few minutes or a few seconds. The charges given the leaf in each case should be as nearly the same as possible.

This form of apparatus was sensitive enough to show the activity of water which was afterward found to possess an activity equivalent to that produced by .06 milligrams uranium per liter of water.

A better, yet a more expensive form of apparatus, consisting of a specially constructed electroscope of the type described by Professor Boltwood[2] of Yale, and used with a boiler of 11 liters capacity was used to test the waters in the neighborhood of South Hadley, Massachusetts. Several springs were found to be highly radioactive, the most active being the same as would be given by 2.75 milligrams of uranium per liter of water.

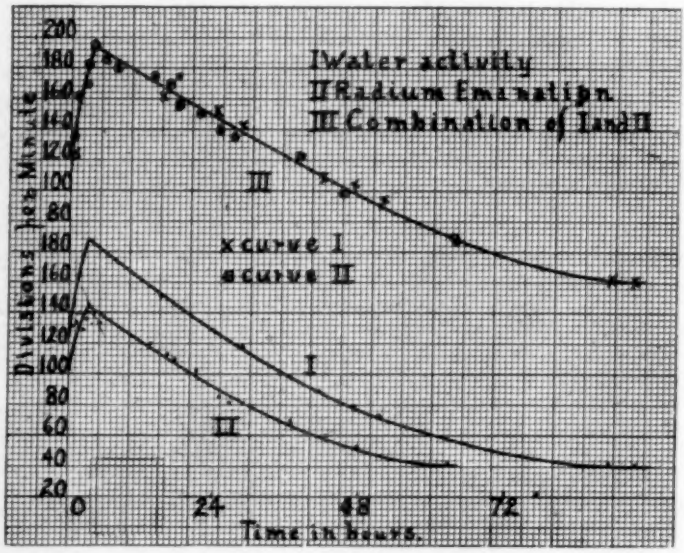
| Sample. | Activity. |
|---|---|
| Campus Spring . . . No. 1. | 2.75 milligrams uranium. |
| Campus Spring . . . No. 2. | 1.65 milligrams uranium. |
| Campus Spring . . . No. 3. | 1.60 milligrams uranium. |
| Lithia Spring . . . | 1.54 milligrams uranium. |
| College Artesian Well . | .06 milligrams uranium. |

The electroscope was standardized by a method suggested by Professor Boltwood.[3] It is the effect produced by the radium emanation obtained from .01 grams uranium in the mineral uraninite which always contains radium emanation in the same proportion as uranium. When the rate of discharge of the gold leaf is known for this amount of emanation, then the readings

[2] Boltwood, American Journal of Science, August, 1904, p. 97.
[3] Boltwood, American Journal of Science, 18, p. 97, 1904.

obtained from the spring water may be reduced to terms of grams or milligrams of uranium.

If the activity discovered in the springs is due to radium emanation the fact may be readily ascertained by comparing the rate at which the activity decays with the period of decay of the




emanation obtained from uraninite used under the same conditions. This is best shown by comparing the curves which represent the periods of decay of the two activities. Curve I shows the water activity, curve II the activity obtained from the uraninite. The resemblance of the two curves is more strikingly shown by increasing the latter curve to the magnitude of the former as is shown in curve III.

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Important researches upon the use of high-pressure steam—up to about 1,500 pounds per square inch—in steam turbines have been conducted by Dr. de Laval. He finds that the present tables giving the properties above 350 pounds pressure—432 deg. F.—are unreliable, the values having been extrapolated. One remarkable deduction is that at about 640 deg. steam seems to have a maximum efficiency. This is apparently paradoxical, for theoretically the thermodynamic efficiency is greater the higher the temperature. The probable explanation is the rapid decrease in the latent heat as the critical temperature—689 deg., according to Cailletet; 698 deg., according to Regnault—is approached.

# INTERCISION, A PECULIAR KIND OF MODIFICATION OF DRAINAGE.

By James Walter Goldthwait,

*Department of Geology, Northwestern University.*

Often during its life a river is subjected to vicissitudes of climate, of contest with neighboring streams, or of some other element of its environment, in competition with which it must either win or suffer serious consequences. In its earliest beginnings, while it may be one of a large number of little wet-weather streams, trickling down an exposed slope, and cutting a little gully for itself, the stream has its fate determined chiefly by (a) the amount of water which is shed into it, (b) the slope of the surface on which it is running, (c) the strength or weakness of the structure in which it is cutting, and especially (d) the space relation which it bears to neighboring streams and (e) the advantages or disadvantages of volume, slope, and structure, which it possesses in comparison with these neighbors. The contest for supremacy between the gullies on a rain-washed slope, and on a larger scale the contest between young, vigorous river systems, is a fierce one, and has very properly been called a "struggle for existence". The manner in which an unfortunate river system may be dwarfed by the rapid growth of its more favored neighbors on either side, which by extending their headwaters appropriate the run-off of the surrounding district, is well known to students and teachers of physiography. The gain of drainage through outright robbery or "piracy" by a stronger stream from a weaker neighbor, is a familiar phenomenon. "Beheaded", "diverted", and "pirate" streams are phrases full of meaning and applicable to many well-established cases of river capture. In this class of diversions of drainage, "stream piracy", even more truly than in the "dwarfing" of streams, we see an illustration of the old rule that "to him that hath shall be given; but to him that hath not shall be taken away even that he hath".

Not only has the term "piracy" found general acceptance and proved to be of great use, but in a recent standard text-book of geology[1] a peculiar variety of the process, in which a portion of a river is believed to have been captured and diverted by one

[1] Chamberlin and Salisbury, "Geology," Vol. 1, p. 105. 1906.

of its own little tributaries has been dignified by the more specific name "domestic piracy."[1] While not all will agree as to the probability of diversions like this supposed case of "domestic piracy" (to accomplish which there are peculiar difficulties to overcome), and while only a single case (viz. on the Dells of the Wisconsin River) has been described, we must admit the expressiveness of the term "domestic piracy" as a short-hand means of reference to a somewhat complex process.

It is the purpose of this paper to describe a peculiar sort of modification of drainage which is slightly allied to river piracy, but in which the diversion is accomplished by the cutting back of bluffs along a lake shore. The lake eats its way inland and cuts into a bend of the valley of a river, some distance above its mouth. In the case here described, the lake is Lake Michigan, and the river from which the lower portion has been severed is Pike River, near Kenosha, Wisconsin. The process will be called *intercision,* adopting a word which expresses the phenomenon as closely as any which has suggested itself. The introduction of this technical term for the single case of Pike River would hardly seem justified but for three reasons. (1) The conditions which lead to intercision are to be found rather generally along the borders of the Great Lakes where the glacial drift is thick, raised beaches and deflected streams are common. and the bluffs of the present shore are receding under the attack of the waves. (2) Though no other example of "intercision" is known to the writer, at least two examples of fossil intercised valleys, of former lake stages, have been observed. One of them is about two miles north of Waukegan, Illinois, and the other is in northern Ozaukee County, Wisconsin. (3) In the case of Pike River, complete intercision is exhibited at one place, while at two other places within a mile the process is on the point of being repeated. Thus it is possible in a single locality to see three stages of the process. It is one of the chief aims of this paper to stimulate search for other cases of "intercision," elsewhere about the Great Lakes, in order that the phenomenon may be shown to fully deserve a name of its own.

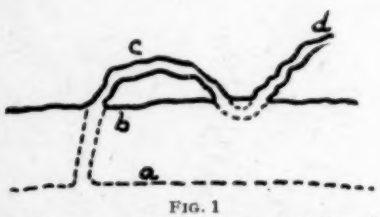

FIG. 1

Fig. 1. The mouth of Pike River. (From Lapham's paper.) *a*, ancient coast. *b*, present cosat, *c*, bayou. *d*, river.

The leading facts of the intercision of Pike River are shown in the small diagram (Fig. 1) and very concisely stated in the following quotation from a paper by I. A. Lapham.[2]

"At Southport, thirty-five miles south of Milwaukee, the bend of a stream has been carried away, so that its valley presents three openings to the lake, as represented in the figure..... where the dotted line represents the ancient state of things and the black lines the modern." Since 1847, so far as known to the writer, no description of the peculiar phenomenon has been written, although it has been noticed by several observers independently of each other and of Lapham's paper, and the state of things is pretty well understood and appreciated by people living in the vicinity. The details of the case, which Lapham did not present, are interesting because they show that the feature is by no means as accidental or abnormal as might at first appear.

On the contour map of the U. S. Geological Survey known as the Racine Quadrangle (of which a small portion is reproduced in Fig. 2) Pike River may be found, just north of the city of Kenosha. While the map shows in a general way the relations of the valley to the shore of Lake Michigan, the scale of it is too small, the contour interval (20 feet) is too large, and the contours too much generalized, to bring out clearly the significant features. A more detailed map of that portion of the district with which we are especially concerned is therefore given in Fig. 3.[3]

The belt of country bordering Lake Michigan between Kenosha and Racine, Wisconsin, and reaching back about two miles (to the 640-foot contour on the Racine Quadrangle), including all the area shown in Fig. 3, is the smooth floor of the extinct glacial Lake Chicago, the ancestor of Lake Michigan. Beneath a veneer of lake-floor silts and beach sands and gravels, is a thick sheet of boulder clay or till, the deposit of the extinct ice sheet. This reaches downward well below the level of Lake Michigan. No bed rock is exposed in the region. The narrow plain between the 640-foot contour and the brink of the lake

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[2] I. A. Lapham. "On the existence of certain lacustrine deposits in the vicinity of the Great Lakes, usually confounded with the drift." *Amer. Jour. Sci.*, 2nd series, vol. 3, pp. 90-94, 1847.

[3] This is a reduced copy of a map illustrating a description of the Pike River locality in Bulletin 17 of the Wisconsin Geol. and Nat. Hist. Survey. "Abandoned shore-lines of eastern Wisconsin." 1906.

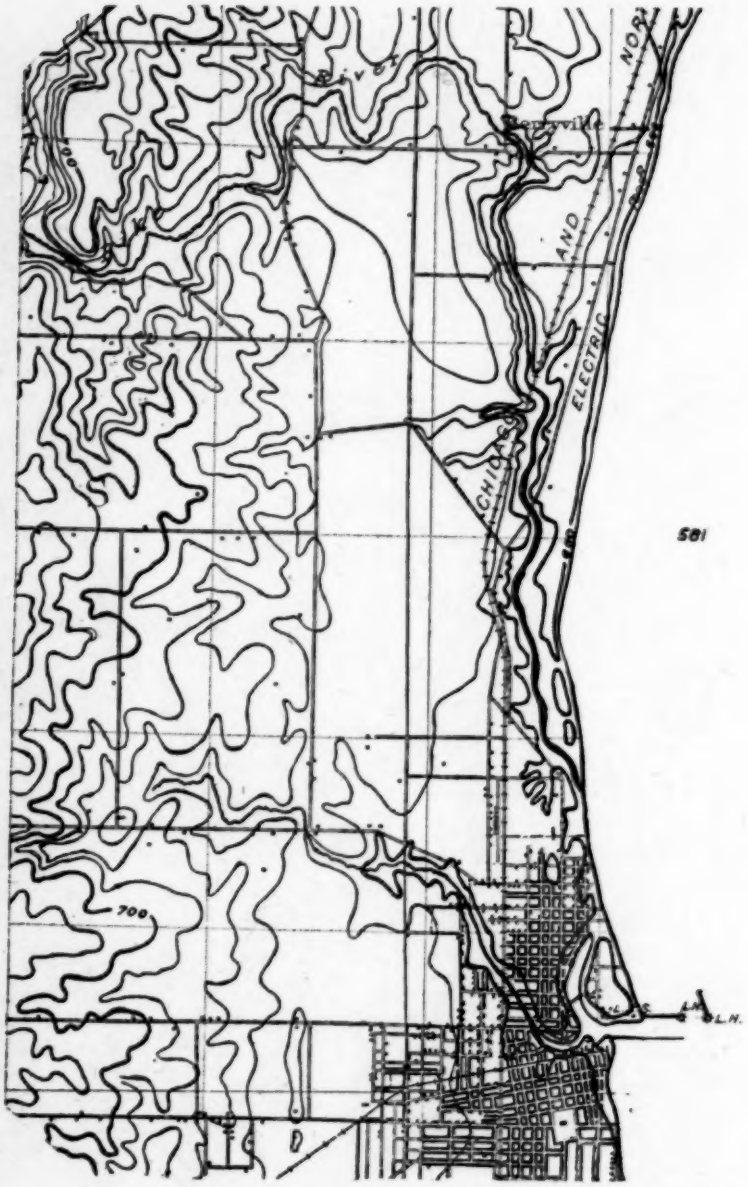


Fig. 2. A portion of the Racine Quadrangle, U. S. Geol. Survey.

bluffs is marked by occasional shore-lines of the extinct lake. They represent stages when the level of the lake was successively 60, 40 and 20 feet above the present level. One of the beach ridges, the highest or 60-foot one, is obscurely shown in Fig. 2 by the 640-foot contour a mile west of Kenosha. In Fig. 3 the course of the second or 40-foot ridge is shown by the 35- and 40-foot contours, west of the Chicago and Northwestern Railway. The course of the 20-foot ridge is lost, north of Kenosha, because Lake Michigan has cut the bluffs westward past the 20-foot shore-line into higher ground. There is reason, however, to put the lost course of this beach not far east of the present shore, and nearly parallel to it.

FIG. 3.

The lower portion of Pike River, from Berryville (Fig. 2) southward to its mouth, runs nearly parallel to the shore of Lake Michigan, and very close to it. In the last mile, especially, (see Fig. 3) the river lies almost within a stone's throw of the lake, but the deep valley in which it runs is separated from the lake almost continuously by a belt of upland of irregular width. The conditions which have led to this parallelism of river valley and shore are not hard to find. That part of Pike River which lies on the old lake floor (viz., all below the 640-foot contour) grew up by extension while the lake was falling from the 640-foot mark to its present 581-foot level. As fast as the flat plain emerged and the lake shore moved eastward, the mouth of Pike River was extended. As far as Berryville this extension was directly towards the lake, but from that point on the mouth of the river was shifted southward. This was due in part to the prevailing southerly drift of material along the shore, under the influence of a shore current, and in part to the presence of long beach ridges of the 40-foot and 20-foot stages, which lay between the river and the lake. In part, also, it was probably due to gently southward inclination of the plain itself. Such deflected courses are plentifully illustrated along the present shores of Lake Michigan and other lakes, and even more abundantly on the adjoining belts of lake plain where the shore-lines of ancient high-level stages very commonly have the form of beach ridges and the stream courses have either been inherited from those of the early stages or have been developed along the floors of the old lagoons behind the ridges.[4]

The falling of the lake from the old 60-foot level to the present one was equivalent to the lowering of the base-level of Pike River sixty feet. All that time, therefore, the river in its deflected course was sinking its channel below the surface of the plain; and today the result is to be seen in the deep, steep-sided valley, with its floor close to lake level.

A point both of beauty and of significance is the gentle winding of the valley from side to side. Within the winding valley the river swings in curves of somewhat smaller radius. The two features, winding valley and meandering river, are genetically connected; the former is due to the latter, although

[4]Such features, for instance, may be seen on the Ann Arbor, Mich., Fostoria, Ohio, and Cleveland, Ohio, Quadrangles of the U. S. Geol. Survey.

the two sets of curves, as just noted, are of different sizes. To explain this we need only remember that the portion of Pike River here concerned was developed on a smooth, gently inclined lake plain, and that on this account the path of the river was more or less definitely meandering from the very beginning. The smoothness and gentle inclination of the lake plain, together with the uniformly weak structure, made it easy for the river to be turned by any irregularity or obstruction, and easy for it to erode the bank at such bends and thus to develop meanders of moderately large radius. Possessing imperfect meanders, therefore, very early in its life, in its new course on the plain, the river kept enlarging the meanders while it was sinking its channel into adjustment with the lowered base-level. By progressive cutting around the outside of each curve, the valley was widened, its sides were steeped and its floor broadened. By the especially strong erosion on the down-valley side of each curve of the river, the alternating spurs (which mark the inside of the original meanders) were trimmed away on their up-valley sides. The consumption of the spurs, so far as it has yet progressed, has tended to straighten the valley; hence the curves of the river today are of somewhat smaller radius than those of its valley. Fig. 3 shows very plainly (1) the winding valley with its steep sides and flat flood plain, (2) the meandering river, sytematically under-cutting the bluffs on the outside of each curve, i. e., the up-valley side of the spur, and (3) the relation of the valley to the neighboring lake shore. Because these bends bring the river closer to the shore at certain points than at others, the process of intercision by an advance of the lake shore is made possible. Hence the value of recognizing that *the winding of the valley is not accidental but systematic,* and that it is characteristic of many rivers which, like this one, have grown up in association with old beaches, on the smooth lake plains bordering the Great Lakes.

Turning now from the river valley to the lake shore which lies so near it, we may note first the line of low cliffs which face the lake along the entire coast, in Fig. 3, except where the long pier at Kenosha has arrested the southerly drift of sand and a triangular patch of beach and dunes has been built up. These cliffs developed by the attack of the waves against the border of the clay upland, are often vertical or even gently overhanging, as the contours in Fig. 3 indicate, so rapidly are they being

trimmed back. During each storm the waves saw horizontally against the base of the clay cliffs, while blocks of the unconsolidated but very compact material slip and tumble off to the water's edge. There they are broken up into small particles and swept along shore or out into deep water. The clay bench at the base of the cliffs, cut by the sawing action, is only imperfectly concealed by gravel and sand, so thoroughly do the waves dispose of the debris. Under ordinary circumstances the fallen material would suffice to maintain a beach of considerable thickness at the foot of the bluffs, but here the attack of the waves is too strong; the transfer of waste more than keeps pace with the supply, and the bluffs rapidly retreat westward. No exact figures can be given here for the exact rate of recession; but reliable measurements collected by Dr. Edmund Andrews in 1868[5] show that the shore at Kenosha was then receding as fast as twelve feet per year, and a few miles south, near the state line, sixteen and a half feet per year. The present rate of retreat is probably as fast as the rate in 1868, and is clearly much faster than the average rate of recession of the shore between Evanston, Illinois, and Milwaukee (which was five and a quarter feet per year in 1868). Three reasons for the exceptionally rapid cliff-recession just north of Kenosha may be suggested. (1) The cliffs here are comparatively low, rising hardly 30 feet from the water's edge instead of 80 or 100 feet, as is the case south of Waukegan, Illinois, and north of Racine, Wisconsin. The higher the cliff, the faster the talus is supplied to the waves on the beach below, and the more difficult it is for them to dispose of the debris. Low bluffs are cut back faster than high bluffs. (2) The strength of the waves depends, among other things, upon the slope of the lake floor bordering the coast. The configuration of the shore off Kenosha may favor heavy wave action. (3) For years the stretch of shore near the mouth of Pike River has been artificially robbed of its beach gravels. The material which the waves are accustomed to "chew on" has been continually denied them, and as a result they have eaten away the bluffs with more than ordinary voracity.

More than half a mile south of the mouth of Pike River (as can be seen in Fig. 3) the shore bluffs are interrupted by a steep-sided valley which heads at the lake and passes obliquely south-southwest to the harbor of Kenosha. The valley has steep,

[5] Quoted by Leverett, "Illinois Glacial Lobe." Monograph 38, U. S. Geol. Surv., p. 486.

straight sides and a uniform width of nearly an eighth of a mile. It is occupied for most of its length by a lagoon or bayou of standing water. The bayou is shut off from the lake at its head by a sandy beach and a line of dunes; but at its south end, near the Life Saving Station and the Yacht Club house, it opens upon the lake at the mouth of Kenosha River. The patch of upland which lies between the lagoon and the lake except for a belt of dunes near the pier, already mentioned, is an extension of the lake plain which borders the coast throughout the district—a smooth-topped, table-like mound of glacial drift with a veneer of lake floor deposits. The oblique valley occupied by the lagoon can not have been developed by the normal process of erosion, alone. Its width is much too great, and too uniform to be thus explained.

As one stands on the bridge over the lagoon and looks towards the northeast, through this valley to the lake, he is impressed with the idea that the upper portion of the valley has been cut away by the advance of the lake on the shore. This impression is strengthened by a study of the position of the valley on the map, where its relation to the valley of Pike River may be seen. The bayou valley lies nearly in line with the valley of the river. It seems surely to be the original lower end of that valley, severed from it by the recession of the lake bluffs westward across the dividing ridge and through the valley itself.

Since the intercision or severing of the lower portion of the river from the upper portion, the advance of the shore has continually widened the original breach, so that the upper end of the severed portion and the lower end of the remaining portion have come to be fully three quarters of a mile apart. If we reconstruct the original valley as Lapham did (see Fig. 1), using for this purpose, however, the larger and more accurate map in Fig. 3, we shall find that the ancient Pike River, at the point where it was first severed, was probably not over a quarter of a mile east of the present lake shore. Assuming then that the bluffs have been cut back not over a quarter of a mile since the intercision occurred, and that the rate of recession has been 12 feet per year (using Andrews' figures), we may estimate that the intercision occurred about 110 years ago. To be sure, we do not know accurately any of the factors in this computation. The course of the lost segment of the valley and its distance east of the present shore, the present rate of recession

and its relation to the rate in preceding decades—these are only approximately known. It seems probable that the advance of the lake in former times was not less rapid than now, since the bluffs have probably increased rather than decreased in height, while they have receded. The intercision may have occurred less than 110 years ago, for this reason. It seems safe at any rate to conclude that the intercision took place before the settlement of "Southport" (Kenosha), though at no very ancient date. A comparison of Lapham's diagram (Fig. 1) with the modern maps suggests that the intercision occurred only a few years before 1847; but it is doubtful if his little diagram was intended to show the width of the breach and the length of the bayou in their true proportions. If any early maps of the district are in existence, it would be interesting to see what light they shed on the rate of recession and the date of intercision.

The narrowness of the severed portion of the valley, at the bayou, as compared with the portion above the present mouth of the river, does not seriously disturb the theory of their former continuity; for since the severing of the parts Pike River may have widened its valley very considerally by lateral erosion.

The interest to be found in this case of Pike River and the usefulness of the locality for teaching the process of intercision is increased by the threatened repetition of the process at a point about half a mile above the mouth. At two points, indeed, within this half mile, the cliffs have been cut back through the east wall of the valley, opening a breach through which one may pass by a few steps from the lake to the river. These two points are determined by two eastward bends of the valley. The more southerly bend, because of its small size and an irregularity in the course of the river, which here swings to the opposite side of its valley, is not likely to become a point of intercision; but the more northerly one is a pronounced bend and the river there swings clear to the outside of the curve—indeed, within about 200 feet of the lake. The disposal of driftwood here shows that during storms the waves run through the breach across the exposed flood plain and almost or quite into the river. Along the beach the edge of the flood plain is exposed in cross section, where it is being trimmed back by the waves. It consists of a black peaty deposit overlying a bed of limonite conglomerate,—gravels cemented with bog iron ore. In any storm, when the

river is flooded and the surf is high, a short cut is likely to be excavated at this point. The mouth of Pike River will thus be shifted half a mile north of its present position and a new intercision will have been accomplished. Until, however, the shore-line has advanced clear across the valley to its west side, and the river has thus been cornered, there will be opportunity still for the short-cut to be blocked by beach gravels or river deposits and for the mouth of the river to be shifted back to the place it now occupies. Intercision cannot be final so long as a remnant of the flood plains remains, along which the river may find its way down the valley.

It should be noted, also, that at still another point, namely one mile north of the present mouth, the river is threatened with intercision. The cliffs have not been cut back so far here as to open a breach (see Fig. 3); but the steep wall of the valley lies only a few rods from the rapidly approaching lake, and unless the shore is artificially protected the severing of the river here is bound to occur in a short time.

In this one case, then, are exhibited *three stages* in the process of intercision; (1) the stage where the cliffs are fast approaching a bend in the river valley, but have not yet reached it; (2) a later stage, in which the shore-line has advance into the valley, causing a breach in the cliffs, but with the river not yet captured; and (3) the completed condition of things,— a bayou and headless valley, severed from the upper portion of the river by a stretch of shore which is constantly increasing in length as the recession of cliffs continues.

## A MODIFICATION OF THE HOLMGREN TEST FOR COLOR BLINDNESS.

By C. M. Westcott,

*Redlands High School, Redlands, Cal.*

The prevalence of color blindness among boys, and the importance of the individual being aware of his deficiency in this respect when it exists, seems to warrant our giving rather more attention to the subject than we generally do in the schools.

Having experienced some inconvenience in using the conventional sets of colored yarns in the schoolroom, the writer has devised a modification of the Holmgren test which seems to serve the purpose admirably.

The set of yarns is replaced by a single lantern slide with different portions numbered and colored accurately to the various colors and shades of the test yarns. The method employed is to throw the colors on the screen and ask the members of the class to each make out a list by number of the different shades of the three test colors. An examination of these lists will betray at a glance anyone deficient in color sense.

The particular advantage of this over the conventional method lies in the fact that the test may be performed on a whole class as easily as on an individual.

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## NOTE ON THE "NODON VALVE."

By Willis E. Tower.

*Englewood High School, Chicago.*

The "Nodon Valve" described in the November, 1907, issue of this journal has brought several letters asking for more information about this useful device.

The original paper upon this apparatus, by Albert Nodon, is to be found in Vol. I of the Proceedings of the International Electrical Congress, St. Louis, 1904, pp. 510-527. The paper describes a series of experiments conducted with a view of determining the most efficient combination of substances for the rectification of alternating currents by electrolytic means. This is found to be a cell containing a saturated solution of ammonium phosphate with electrodes of sheet aluminum and of sheet lead. Sodium and Potassium phosphates may be used, but these liberate

metallic sodium and potassium which attack the electrodes, causing imperfect action. While one cell will work, four cells are better. The first uses but one alternation, the other both with an efficiency given at 70 per cent. The connections are shown in the November article.

In action, one alternation passes through the cell easily, leaving by the aluminum plate. On the reversal, a non-conducting film of oxide forms on this plate, preventing passage of the reverse current, the direct alternation immediately succeeding passing as at first. The four-cell combination gives a pulsating current in one direction, which may be rendered nearly uniform by connecting in parallel with the valve a condenser composed of sheets of aluminum hung in a solution of aluminum phosphate.

Helpful articles on the electrolytic rectifier are also to be found in the *Scientific American Supplement* of July 6, 1907, and in the *Scientific American* of August 24, 1907.

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## A COMMUNICATION

Racine, Wis., Dec. 10, 1907.

Mr. G. W. Myers, Chicago, Ill.

DEAR SIR: The ordinary algebraic method of solving indeterminate equations is of little educational value to the average pupil. He readily learns the rule and is able to grind out results, but he doesn't clearly see the reason why. The following graphical method is very simple and easily understood and is much more reasonable than the algebraic method. The method is this: Plot the locus of the equation. If the locus has a negative slope the problem will ask for all positive integral values of the two unknowns, and if it has a positive slope the lowest pair of postive integral values will be the ones required. In the first case take all the points in the first quadrant (when $x$ and $y$ are both plus) where the locus crosses the intersection of the horizontal and vertical lines. In the second case take the lowest point. Counting up and out we have the value of $y$ and of $x$ for each given point. As a check these values may be substituted in the equation.

Here is an example. Solve in positive intergers:

$3x + 5y = 29.$

$y = -\frac{3}{5}x + \frac{29}{5}.$

Let $x = o$, $\therefore y = \frac{29}{5}$.

Let $x = 7$, $\therefore y = \frac{8}{5}$.

The solutions are

$x = 3$, $y = 4.$

$x = 8$, $y = 1.$

Yours truly,

HENRY ERICSON,

Racine High School.

## PROBLEM DEPARTMENT.

IRA M. DELONG,

*University of Colorado, Boulder, Colo.*

*Readers of the Magazine are invited to send solutions of the problems in this department and also to propose problems in which they are interested. Problems and solutions will be duly credited to their authors. Address all communications to Ira M. DeLong, Boulder, Colo.*

### Algebra.

Solve $x^2+y^2+xy=19$ .....(1)

$y^2+z^2+yz=7$ .....(3)

*Solution by Geo. W. Hartwell, Columbia University, N. Y.*

Multiply (1) by $(x-y)$, (2) by $(z-x)$, (3) by $(y-z)$

$x^3-y^3=19\ (x-y)$ .....(4)

$z^3-x^3=13\ (z-x)$ .....(5)

$y^3-z^3=7\ (y-z)$ .....(6)

Adding (4), (5) and (6) and solving the resulting equation for $y$

$$y=\frac{x+z}{2} \quad \text{.....(7)}$$

By means of (7) eliminate $y$ from (3)

$7z^2+x^2+4zx=28$ .....(8)

Subtract (8) from 4 times (2) and divide by 3

$x^2-z^2=8$ .....(9)

Adding (9) and (2)

$$z=\frac{21-2x^2}{x}$$

Substituting these values of $z$ in (9)

$3x^4-76x^2+441=0$

$\therefore x^2=9\ ,\ \frac{49}{3}$.

Therefore:

$x=3, \quad y=2, \quad z=1$

$x=-3, \quad y=-2, \quad z=-1$

$x=\frac{1}{3}\sqrt{3}, \quad y=-\frac{7}{3}\sqrt{3}, \quad z=-\frac{1}{3}\sqrt{3}$

$x=-\frac{1}{3}\sqrt{3}, \quad y=\frac{7}{3}\sqrt{3}, \quad z=\frac{1}{3}\sqrt{3}$.

### Geometry.

83. *Proposed by I. L. Winckler, Cleveland, Ohio.*

Three circles, radii $a$, $b$, $c$, are drawn in a triangle, each circle touching the other two and two sides of the triangle. Find the sides of the triangle.—(*Mathematical Visitor*, 1878.)

I. *Solution by H. E. Trefethen, Kent's Hill, Maine.*

Let $a > b > c$. Denote the vertices of the circumscribing triangle by A, B, C. Join the centers, $a$, $b$, $c$, and in the triangle thus formed put $\alpha\ \beta\ \gamma$ for the angles, which are known since the sides $a+b$, $b+c$, $a+c$ are given.

From the center of each circle draw perpendiculars to the sides of triangle ABC at the points of contact. Draw also the lines $aA$, $bB$, $cC$, bisecting the angles A, B, C. From center of circle $c$ draw lines parallel to CA meeting $aA$ at $a'$ and to CB meeting $bB$ at $b'$ and join $a'b'$ parallel to AB. The angles of the triangle $a'b'c$ are equal respectively to the angles A, B, C and hence

$$A = \alpha - \text{arc sin } (a-b)/(a+b) - \text{arc sin } (a-c)/(a+c)$$
$$B = \beta + \text{arc sin } (a-b)/(a+b) - \text{arc sin } (b-c)/(b+c)$$
$$C = \gamma + \text{arc sin } (a-c)/(a+c) + \text{arc sin } (b-c)/(b+c)$$

Each side of the triangle ABC is divided into three segments by the perpendiculars. Therefore

$$AB = 2\sqrt{ab} + a \cot \tfrac{1}{2}A + b \cot \tfrac{1}{2}B.$$
$$BC = 2\sqrt{bc} + b \cot \tfrac{1}{2}B + c \cot \tfrac{1}{2}C.$$
$$AC = 2\sqrt{ac} + a \cot \tfrac{1}{2}A + c \cot \tfrac{1}{2}C.$$

II. *Solution by H. C. Whitaker, Ph.D., Philadelphia, Pa.*

If the angles of the triangle are denoted by A, B, C, then by a well known property of the Malfatti Circles* of radii $a$, $b$, $c$,

$$\sqrt{a}(1+\tan\tfrac{1}{4}A) = \sqrt{b}(1+\tan\tfrac{1}{4}B) = \sqrt{c}(1+\tan\tfrac{1}{4}C).$$

These two equations and the relation $A+B+C=180°$ give three equations to determne A, B, C. Then the lengths of the sides are

$$b \cot\tfrac{1}{2}B + 2\sqrt{bc} + c \cot\tfrac{1}{2}C$$
$$c \cot\tfrac{1}{2}C + 2\sqrt{ca} + a \cot\tfrac{1}{2}A$$
$$a \cot\tfrac{1}{2}A + 2\sqrt{ab} + b \cot\tfrac{1}{2}B$$

[NOTE. Dr. G. B. M. Zerr and Mr. I. L. Winckler computed the lengths of the sides to be:

$$\frac{(a+b)^2[c\sqrt{ab} - b\sqrt{ac} - a\sqrt{bc} + c\{\sqrt{as}+\sqrt{bs}+\sqrt{cs}\{-\sqrt{abcs}+cs]}{\{a\sqrt{c}+c\sqrt{a}+\sqrt{acs}-b\sqrt{s}\}\{b\sqrt{c}+c\sqrt{b}+bcs-a\sqrt{s}\}} = AB,$$

where $s=a+b+c$ and then find AC and BC by interchanging letters. ED.]

84. *Proposed by E. L. Brown, M.A., Denver, Colo.*

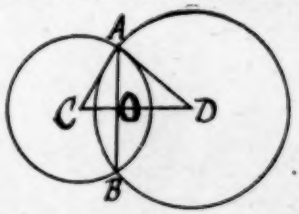
A circular field contains one acre. A horse is tied to a tree 20 feet from the field with a rope of sufficient length so that he can graze over one-fourth of the circular field. How long is the rope?

*Solution by G. B. M. Zerr, Ph.D., Philadelphia, Pa.*

Let C be the center of the field, D the point where the rope is fastened. Denote CD by $a$. Then $CO^2+OA^2=R^2$, $(a-CO)^2+OA^2=r^2$. Therefore

$$CO = \frac{a^2 + R^2 - r^2}{2a}, \text{ and}$$

$$AO = \frac{\sqrt{2a^2R^2 + 2a^2r^2 + 2R^2r^2 - a^4 - R^4 - r^4}}{2a} = b.$$




The area common to the two circles is:

$$R^2\sin^{-1}\frac{b}{R} - b\sqrt{R^2-b^2} + r^2\sin^{-1}\frac{b}{r} - b\sqrt{r^2-b^2} = \tfrac{1}{4}\pi R^2.$$

*Elements of Trigonometry, by H. C. Whitaker, published by Eldredge & Brother, Philadelphia, 1899, page 107.—ED.

$$\therefore R^2\sin^{-1}\frac{b}{r}\,R + r^2\sin^{-1}\frac{b}{r} = \tfrac{1}{2}\pi R^2 + ab,$$

to find $r$.

$$R = 4\sqrt{\frac{\pi}{10}} \text{ rods} = 114.752 \text{ feet}; \quad a = R + 20 = 137{,}752 \text{ feet}.$$

$$\therefore b = \frac{\sqrt{65682.294r^2 - r^4 - 26112917.607}}{275.504}.$$

By the lengthy method of double position we find $r = 107.5$ feet, nearly.

## Trigonometry.

85. *Proposed by H. L. McAlister, Arkadelphia, Ark.*

A statue 10 ft. high standing on a column, subtends, at a point 100 ft. from the base of the column and in the same horizontal plane, the same angle as that subtended by a man 6 ft. high, standing at the foot of the column. Find the height of the column.—(Lyman & Goddard's Trigonometry.)

*Solution by James Albert Whitted, Abingdon, Ill.*

Let $h$=the height of the column in feet; $\phi$=the angle subtended by the column+the statue, $\theta$=the angle subtended by the man whose height is 6 feet. Then $\theta$=angle subtended by the statue at a distance of 100 ft. from the base.

We have $$\tan\phi = \frac{10 + h}{100} \quad \ldots\ldots (1)$$

$$\tan\theta = \tfrac{6}{100} = \tfrac{3}{50} \quad \ldots\ldots (2)$$

$$\tan(\phi - \theta) = \tfrac{h}{100} \quad \ldots\ldots (3)$$

From the last of these equations we obtain:

$$\tan\phi = \frac{h + 100\tan\theta}{100 - h\tan\theta} \quad \ldots\ldots (4)$$

Eliminating $\tan\phi$ from (1) and (4)

$$\frac{10 + h}{100} = \frac{h + 100\tan\theta}{100 - h\tan\theta}.$$

Substituting the value of $\tan\theta$ from (2) and reducing

$$3h^2 - 30h - 20000 = 0,$$

whence $h$=76.8 ft.

## Miscellaneous.

86. *Proposed by Ira P. Baldwin, Emporia, Kans.*

A bather, standing on the bank of a circular pond three miles in circumference, wishes to reach the point directly opposite in the shortest time possible. If he can swim at the rate of 5 miles an hour and run at the rate of 6 miles an hour, what point should he swim toward?

*Solution by E. L. Brown, M.A., Denver, Colo.*

Let the bather be at A and trying to reach the diametrically opposite point D. Suppose he swims to C. Let angle ADC= $\theta$, $r$=rate of swimming, $r'$ the rate of walking.

$\therefore\ t = 2\frac{R}{r}\sin\theta + \frac{(\pi - 2\theta)R}{r'}$, $\frac{dt}{d\theta} = \frac{2R}{r}(\cos\theta - \frac{r}{r'})$.....(1);

$\frac{d^2t}{d\theta^2} = -2\frac{R}{r}\sin\theta$. Since $\frac{d^2t}{d\theta^2}$ is negative, $t$ is a maximum when $\theta = \cos^{-1}\frac{r}{r'}$.

From (1) we see that $\frac{dt}{d\theta}$ is positive as $\theta$ varies from 0 to $\cos^{-1}(\frac{r}{r'})$ and negative as $\theta$ varies from $\cos^{-1}(\frac{r}{r'})$ to $\frac{\pi}{2}$.

Hence $t$ is a minimum when the bather travels along the diameter.

## CREDIT FOR SOLUTIONS RECEIVED.

Algebra 62. Howard C. Raymond.

Algebra 77. Esther M. Venables.

Algebra 78. Geo. W. Hartwell, Esther V. Venables.

Algebra 82. Henry A. Converse, W. L. Malone, Mary Clemmer Tracy, C. Z. Aughenbaugh, Earle A. Childs, G. B. M. Zerr, W. E. Lugenbeel, H. C. Feemster, H. E Trefethen, James A Whitted, H C. Whitaker, John H. Bortz, Geo. W. Hartwell, A. W. Rich, E. L. Brown. I. L. Winckler.

Geometry 83. G. B. M. Zerr, I. L. Winckler, H. E. Trefethen, H. C. Whitaker, E. L. Brown (two solutions).

Geometry 84. H. C. Whitaker, H. E. Trefethen, G. B. M. Zerr, E. L. Brown, F. P. Garrard.

Trigonometry 85. H. C. Feemester, C. E. Wheeler, G. B. M. Zerr, Geo. W. Hartwell, Mary Clemmer Tracy, W. L. Malone, H. E. Trefethen, John H. Bortz, James H. Whitted, A. W. Rich, E. L. Brown, I. L. Winckler. Also one incorrect solution.

Miscellaneous 86. W. L. Malone, G. B. M. Zerr (two solutions), Wm. B. Borgers, H. E. Trefethen (two solutions), E. L. Brown. Also two incorrect solutions.

Total number of solutions, 53.

## PROBLEMS FOR SOLUTION.

### Algebra.

92. *Proposed by H. E. Trefethen, Kent's Hill, Me.*

Two men engage to build twenty rods of stone wall. The stones are all in a pile at one end, and they agree that it is as much work to move the stones as to lay the wall. A begins at the pile of stones and B at the other end. How many rods ought each to build to do half the work?

### Geometry.

93. *Proposed by O. S. Hoover, Laton, Cal.*

If from the vertices of any triangle straight lines be drawn to the points where the inscribed circle touches the sides, these lines are concurrent (Ex. 20, page 274, Ray's Geometry and Trigonometry). A proof without using Ceva's Theorem preferred.

94. *Proposed by I. N. Warner, Normal, Ill.*

Upon the given line AB construct a regular pentagon.

95. *Proposed by I. L. Winckler, Cleveland, Ohio.*

Construct a triangle, having given the base, the line bisecting the vertical angle and the diameter of the circumscribing circle.

**Trigonometry.**

96. *Proposed by H. E. Trefethen, Kent's Hill, Me.*

In a plane triangle, given

$b=a \sin C$ and $c=a \cos B$.

Find all the angles.

**Miscellaneous.**

97. *Proposed by W. L. Malone, Fern Hill, Washington.*

A courier and a bather start at the same time from the same point on the bank of a circular pond, radius $r$, the one to run round the pond at the rate of $a$ miles per hour, the other to swim at the rate of $b$ miles per hour $(a > b)$. Toward what point must the bather swim so as to arrive at the same time as the courier ,and how far will each have travelled?

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## ORGANIZATION MEETING OF ILLINOIS STATE ACADEMY OF SCIENCE.

More than one hundred persons gathered in the Senate Chamber at Springfield at ten o'clock Saturday morning, Decemer 7, for the purpose of organizing a State Academy. The meeting was called to order by A. R. Crook, curator of the State Museum, and U. S. Grant, Northwestern University, was elected chairman.

T. C. Chamberlin, University of Chicago, gave an address on the advantages of a state academy. He extended greetings to the company assembled from the Chicago Academy of Sciences, which for thirty years has been engaged in furthering scientific work in the state of Illinois. He said that an important part of his message would consist of suggestions against errors which might endanger the organization. The chief part of his address, which will appear in full in SCIENCE, concerned itself with the importance of disseminating a love for truth and the opportunity which scientific facts present of increasing right habits of thinking on all questions.

S. A. Forbes, University of Illinois, gave a history of the formation and existence of former State Natural History societies. He called attention to the small number of scientific men in the State at the time when such organizations had their existence; pointed out the difference in present conditions; and showed the promise which there is of an important present and glowing future for the State organization. His address will be given in full in SCIENCE.

The Chair appointed as committee on organization: S. W. Williston, University of Chicago; Wm. A. Noyes, University of Illinois; C. B. Atwell, Northwestern.

And these three selected to complete the committee of nine called for: T. C. Chamberlain, University of Chicago; S. A. Forbes, University of

Illinois; A. R. Crook, of State Museum; Fred L. Charles, State Normal; H. V. Neal of Knox College; B. B. James, James Millikin University.

At 2 P. M. the committee on organization reported with a constitution. The report was considered item by item and the constitution was adopted. The following officers were elected:

President, Prof. T. C. Chamberlin, LL.D., University of Chicago.

Vice-President, Prof. Henry Crew, Ph.D., Northwestern University.

Secretary, A. R. Crook, Ph.D., Curator, State Museum.

Treasurer, Prof. J. C. Hessler, Ph.D., James Millikin University.

Dr. H. Foster Bain, State Geologist, was appointed member of publication committee.

The committee on membership consists of:

Prof. S. A. Forbes, LL.D., University of Illinois.

Prof. T. W. Galloway, James Millikin University.

Prof. J. P. Magnusson, Ph.D., Augustana College.

C. H. Smith, Hyde Park High School, Chicago.

Prof. B. B. James, James Millikin University.

After the organization was complete, ten-minute addresses were given in a symposium on the outlook for young men in science. All of the speakers took an optimistic view of the situation.

W. J. McGee, as a guest of the occasion, represented the outlook in anthropology. The recognition and financial rewards to the worker in this branch are probably less than in many other branches of science, but the amount of work which remains to build the science into goodly proportions is great.

Dr. Coulter called attention to the many fields which are open to the worker in botany. Rewards are promised to the original worker, to the teacher, and to men who would be satisfied with the less attractive but none the less useful work of cataloging the flora of various regions.

Dr. Noyes finds the outlook for workers in chemistry not only attractive scientifically, but financially as well.

Dr. Bain considers the work of investigation and of practical application of geology to be in the main very alluring.

Dr. Crew pointed out the vast amount of investigational work which lies before the physicist, although anyone who enters the door of pure physics will find written before the entrance: "Leave behind the hope of wealth, All ye who enter here."

Dr. Neal read letters from various leaders in the teaching of zoölogy in many institutions, showing that the call for workers and investigators in zoölogy was great, and concluded that zoölogy offers a most attractive field for men whose ambition is not wealth but a competence.

An informal dinner was enjoyed at six o'clock by about seventy-five persons.

In the evening, to an audience of about six hundred, Dr. W. J. McGee gave his lecture on "Greater Steps in Human Progress."

The interest which was displayed throughout the meeting argues well for a successful and useful career for the society. A. R. CROOK.

## TREASURER'S REPORT OF THE CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS.

**Nov. 29, 1906—Nov. 25, 1907.**

RECEIPTS.

| | | | |
|---|---|---|---|
| Balance shown by last report | | | $203.31 |
| Dues—228 Members, @ $2.00 | | | $456.00 |
| " 2 " @ 1 1/3 Yr., @ $2.67 | | | 5.34 |
| " 1 " 1 1/3 Yr., @ 2.50 | | | 3.25 |
| " 1 " 1/3 Yr., @ 2.00 | | | .67 |
| " 6 " (Without S. S. and M.), @ $1.00 | | | 6.00 |
| " 7 " (See Note 1) @ .50 | | | 3.50 |
| " 1 " " " @ 1.00 | | | 1.00 |
| " 57 " Local Center @ 1.50 | | | 85.50 |
| " 1 " " " (S. S. & M. Sept.-Dec.) @ $1.00 | | | 1.00 |
| " 13 " " " (Note 1) @ 50 | | | 6.50 |
| " 2 " To date of resignation | | | .80 |
| Back Dues, 3 " @ $2.00 | | | 6.00 |
| " " 1 " (Note 1) | | | 1.00 |
| Sale of Dinner Tickets, Nov. 30, 1906 | | | 90.00 |
| Sale of Reports on Correlation | | | 2.95 |
| Advertisements in 1906 Program (See Note 2) | | | 83.00 |
| Exchange on Checks | | | .10 |
| | | | 752.61 |
| | | | $955.92 |

Note 1. Subscription to SCHOOL SCIENCE AND MATHEMATICS paid directly to the publishers.

Note. 2. $70.00 had been received from this source before Nov. 29, 1906.

EXPENDITURES.

| | | |
|---|---|---|
| Publishers of SCHOOL SCIENCE AND MATHEMATICS | | $446.79 |
| Expenses 1906 Meeting | | 72.10 |
| " Dinner, Nov. 30, 1906 | | 88.00 |
| " President, Secretary, and Section Officers | | 21.13 |
| " Sec.-Treas. Supplies, Express, etc. | | 17.88 |
| " " Postage | | 14.40 |
| " " Bond | | 10.00 |
| " Executive Committee | | 8.50 |
| " Local Center Committee | | 1.20 |
| " Federation Committee | | 6.50 |
| " Chicago Center | | .65 |
| " Balance on 1906 Program, *(see note) | | 83.92 |
| Refunded on Dinner Tickets, Nov. 30, 1906 | | 2.50 |
| Exchange and Money Orders | | .68 |
| | | $774.25 |
| Balance Cash on Hand | | 181.67 |
| | | $955.92 |

*Note. $62.95 paid on account of Program and Circulars before Nov. 30, 1906.

The Secretary-Treasurer Reported a Summary of Membership as follows:

| | |
|---|---|
| Paid Members, Nov. 29, 1906 | 358 |
| Honorary Members, Nov. 29, 1906 | 4. |
| New Members, Nov. 29, 1906-Nov. 28, 1907 | 101 |
| | 459 |
| Resigned during the year | 22 |
| Total Membership | 437 |
| Expired during year (kept on rolls as per constitution) | 100 |
| Paid Membership, Nov. 28, 1907 | 337 |
| Honorary Members " " | 4. |

## A MATHEMATICAL NOTE AND QUERY.

Permit a quotation from the paper on "Mathematics in California Schools" (SCHOOL SCIENCE AND MATHEMATICS, Dec., 1907, p. 764.) "A proof of the commutative, associative, and distributive laws would be lost on the majority of pupils during the early months of the study of algebra; but, * * * at some time in the course, a proof of these laws * * * should be offered for the benefit of the few who can appreciate them." In several recent texts on elementary algebra this view is adopted and proofs of these laws are given. On the other hand, Chrystal [Text Book of Algebra, 5th Ed., Chap. I, § 27] says: "To speak, as is sometimes done, of the proof of these laws in all their generality is an abuse of terms. *They are simply laid down as the canons of the science.* The best evidence that this is their real position is the fact that algebras are in use whose fundamental laws differ from those of ordinary algebra" [the italics mine]. Perhaps some of you readers may be willing to explain fully why it is desirable in elementary texts on algebra to adopt the position indicated by the first quotation rather than that taken by Chrystal in his treatise on algebra.

T. E. M.

## PERSONAL NOTE.

George P. Knox, principal of the Yeatman High School, has been promoted by unanimous vote of the Board of Education of St. Louis, Mo., to the office of assistant superintendent of instruction. The appointment is made to fill an unexpired term which ends on September 19, 1909. Mr. Knox has been connected with the St. Louis schools for five years. For several years after his graduation he was an instructor in chemistry at Cornell University.

## DEPARTMENT OF SCIENCE QUESTIONS.

By Franklin T. Jones,

*University School, Cleveland, O.*

Is chemistry receiving the attention it should in secondary schools?

Is there any reason why chemistry should not have as prominent a place in the curriculum as physics?

Is not chemistry better suited to high school study than physics?

These three questions were asked in the December, 1907, number of School Science and Mathematics. A discussion of the points involved ought to be stimulating to chemistry as well as physics teaching. Send in opinions to the editor. The results will be printed in a later issue.

### By Examination or Certificate?

Two systems of admission to college exist in the United States—(1) the examination system adhered to by Bryn Mawr, Harvard, Princeton, Yale, Massachusetts Institute of Technology, and Case School of Applied Sciences, rigidly, and by Cornell in English only; and (2) the certificate system adhered to by practically all the other educational institutions in the United States.

What effects do these requirements have on the teaching of physics and chemistry? Is the teaching more effective for those students who are compelled to take examinations or less? Do the examinations serve to hamper the work of teachers? Does the lack of an examination by the college encourage careless teaching?

Is it the ordinary thing to look upon the college as a tyrannical overlord requiring unjust and impossible things of teacher and pupil in the secondary school? There is no question that more thorough and more careful instruction has to be given to a pupil when he is to take a college entrance examination. In these columns a great variety of such examination papers have been printed in order that each teacher may decide whether the questions are fair, whether they require more than can reasonably be accomplished in the average school, whether they are on fundamentals. I think all will agree that, while criticisms of individual questions or even individual papers are unjust, if their pupils could not have attained a passing mark—50 to 60 per cent—on the papers published, they would regard the results of their teaching as unsatisfactory.

The fact is that a considerable per cent even of those who have been specially prepared for the examinations fail. Where does the difficulty lie? Not altogether with the questions. Though some are poor, the great majority are of a kind that our pupils should answer *if they have learned the fundamentals.* Here lies the real difficulty. Too much time is frittered away in non-essentials—fads of teacher or pupil—and insufficient time is given to testing the pupil's knowledge.

Would all schools not be benefited by a uniform system of science examinations to cover a safe minimum of fundamentals required for admission to college?

### Department of Zoology.

Observers of the trend of thought in matters of pedagogy must have noticed that science teachers themselves are doing important work in that field. With a wealth of experience at their disposal, they are formulating their own problems and making discoveries that bear upon the whole question of what is profitable in education. The article by Professor Galloway in this issue of SCHOOL SCIENCE AND MATHEMATICS is a signal contribution to pedagogy in that biology is shown to have value for training in methods of thought.

If biologists can demonstrate that their science may be made fundamentally useful in training the young in habits of full and satisfactory living, they will have done a great service to education.

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## OPTICAL FIRMS UNITE.

It is announced that the firms of Bausch & Lomb, Saegmuller Co., and Carl Zeiss Optical Works have united under the firm name of Bausch & Lomb Optical Company of Rochester, N. Y. The association took effect January 1.

The firm of Bausch & Lomb have not only been pioneers in the manufacture of eyeglasses and lenses in the United States, but they have made possible the more extended use of the microscope in home, school, and commercial life. It is due to them, too, more than any other one firm that photography has become familiar to such a vast army of people by their making it possible to secure high grade lenses at reasonable cost.

This new firm will now be able to use the scientific staff, data formulæ, the inventions of Carl Zeiss, and everything else belonging to the individual firms, to the best possible advantage, for the benefit of their enormous trade in all parts of the world.

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## SOME LOSSES OF CHEMISTS IN 1907.

The year 1907 has taken from us more eminent chemists than any other within our memory. In December and January, Neuman, Koenigs, and Konowalow were called away. February took Mendeluff, the famous discoverer of the Periodic Law; Menschutkin from the same country; Roozeboom from Holland; Otto from Germany; and on the 21st Moissau whose work at Paris has been so fruitful along high temperature lines.

The following month France lost M. Berthelot, her most learned chemist and honored citizen.

In July the famous discoverer of coal tar colors, Sir William Henry Perkin of Sudbury, England, passed away.

While September deprived us of our fellow-countryman W. O. Atwater.

A. L. S.

## NOTE ON THE USE OF FRACTIONAL EXPONENTS.

By Robert L. Short, Chicago.

Improvement in the teaching of algebra has been occupying the minds of educators for the past few years, and much good and some harm has resulted. For the most part attention has been centered on the character of problems, the manipulation of formulæ, and on graphs. American people are faddists, and in some cases the pendulum has swung too far. Some have tried to teach analytics, astronomy, and various other kinds of pure and applied mathematics to the fourteen-year-old boy. Much good has been done, however, and the pendulum is now swinging back. We will be all the better for some flights we have taken and can choose from the whole that which is good and which is adapted to our needs.

One important phase of algebra work has, until now, escaped unscathed, namely: improvement in the teaching of irrational and imaginary numbers. Operation with radical forms is always troublesome to the pupil and, therefore, to the teacher. When the use of the fractional exponent is emphasized, the haze which enveiopes the pupil disappears.

1. Drill the pupil on his exponential laws. Make him feel that they hold, whatever finite number the exponent may be.

2. Throw all radicals into exponential forms. The square of $\sqrt{a+b}$ means nothing to the beginner of average ability. However, $[(a+b)^{\frac{1}{2}}]^2$ means $(a+b)^{\frac{1}{2}}$. $(a+b)^{\frac{1}{2}}$ and adding exponents this becomes $a+b$. Or using the exponent law for powers the result is immediately reached. It is an easy step from

$$(a^{\frac{1}{2}} + b^{\frac{1}{2}})^2 = a + 2a^{\frac{1}{2}}b^{\frac{1}{2}} + b$$

$$\text{to } (2^{\frac{1}{2}} + 3^{\frac{1}{2}})^2 = 2 + 2.6^{\frac{1}{2}} + 3,$$

and from there to finding the square root of $5+2.6^{\frac{1}{2}}$.

The fractional exponent is especially helpful in imaginaries. It is probable that one could not find a teacher who does not have trouble with $\sqrt{-1})^2$ because the student insists that since like signs give plus his result should be $+1$. This difficulty disappears when $(-1)^{\frac{1}{2}}$ is multiplied by $(-1)^{\frac{1}{2}}$, as the adding of the exponents is the only operation that occurs to the pupil. Fractional exponents lend themselves readily to reduction of radicals and to solution of radical equations:

1. $\sqrt{90} \div \sqrt{5} = 90^{\frac{1}{2}} = 5^{\frac{1}{2}} = 18^{\frac{1}{2}} = (3^2)^{\frac{1}{2}} 2^{\frac{1}{2}} = 3\sqrt{2}$.

2. $\sqrt[5]{(4\sqrt{2})} = 2^{\frac{2}{5}} \cdot 2^{\frac{2}{10}} = 2^{\frac{4}{10}} \cdot 2^{\frac{1}{10}} = 2^{\frac{1}{2}}$.

3. $(2x)^{\frac{1}{2}} - (2x+5)^{\frac{1}{2}} = -\dfrac{10}{(2x+5)^{\frac{1}{2}}}$.

whence, $4x^2 + 10x)^{\frac{1}{2}} - 2x - 5 = -10$, etc.

The application of exponential laws is so simple that the pupil fails to find difficulties if radicals are changed to exponential forms. If teachers of mathematics in both college and secondary schools will frown on radical forms they can be as readily banished as has the case system in arithmetic and algebra, where no thought in the solution

of the problem was necessary because a substitution in the formulæ would solve any problem in that list, or the banishment of the exclusiveness of $x$, $y$ and $z$ in the unknowns.

Such reform is sadly needed and the writer would like to see radical notation gradually reduced to a "has been."

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## ARTICLES IN CURRENT MAGAZINES.

*American Naturalist* for November: "Earthworms as Planters of Trees," by Professor E. A. Andrews; "Response of Toads to Sound Stimuli," by S. A. Courtis.

*Forestry and Irrigation* for December: "Lumbering Possibilities, Agusan Valley, Philippine Islands"; "Manufacture of Matches Takes Much Fine Timber"; "Private Forestry as an Investment in the United States," by Ernest Bruncken; "The Wrongs of Mother Earth," poem by Robert Stephenson; "Work in a National Forest—No. 5: Holding Down a Mountain Fire," illustrated, by C. H. Shinn; "Russian Mulberry in a Good Situation," illustrated; "Sterilization and Preservation of Electric Line Poles," by H. P. Folsom, Circleville, O.; "Marking in a Western Yellow Pine Forest," by M. B. Pratt.

*Garden Magazine* for January: "Hardy Plants that are Attractive all Winter," T. McAdam; "All the Cattleyas Worth Growing," Leonard Barron; "How to Make a Water-lily Pond," Henri Hus; "Nine Iron-clad Palms for the Window Garden," P. T. Barnes; "The Best Conifers South and North—I," P. J. Berckmans.

*Nature Study Review* for October: "Nature Study Course," E. R. Downing; "Educational Value of School Gardens," L. A. Hatch; "Study of Germination," H. N. Loomis. For December: "Nature Study Point of View in Agriculture," L. H. Bailey; "Criteria of Selection of Material for Nature Study and Geography," Otis W. Caldwell.

*Open Court* for January: "Galileo Galilei," by Paul Carus.

*Ores and Metals* for December 5: "How Long Will Our Coal Supply Meet the Increasing Demand of Commerce?" E. W. Parker; "The Manufacture of Portland Cement," Richard K. Meade.

*Outing* for December: "Animal and Plant Intelligence," John Burroughs.

*Photo Era* for December: "How to Color Photographs," B. I. Barrett; "The Photo-Chemical Activity of Uranium Nitrate," George F. Parmenter, Ph.D.; "The Oil Pigment Process," E. O. Hoppé; "On the Care and Use of Lantern Slides," F. A. Waugh; "How Far to Develop," Phil M. Riley; "Varnishing Negatives," Victor Wilson.

*Popular Science Monthly* for January: "The Institute of France and other Learned Scientific Societies," Dr. Edward F. Williams; "The Grayling at Caribou Crossing," President David Starr Jordan; "What is Matter?" Dr. S. E. Mezes; "Farm Tenancy, a Problem in American Agriculture," Professor Homer C. Price; "Some Recent Transmutations," Professor Charles Baskerville; "The Rule of the Road," Dr. George M. Gould; "Gold," H. F. Wagenen; "How shall We Improve our Race?" Dr. Gustave Michaud; "A Trip Around Iceland," L. P. Gratacap.

*Review of Reviews* for November: "The Lumber Industry of America," by Milton O. Nelson, with illustrations; "Dr. Robertson and the Training of Canadian Farmers," by George Iles, with portraits and other illustrations; "The Milk Supply as a National Problem," by Charles Culver Johnson, with illustrations; "How Boston Solved the Gas Problem," by Louis D. Brandeis, with illustrations.

*Scientific American Supplement* for December 28: "The Geology of the Klondike," by Dr. Willis E. Everette. January 4: "The Geology of the Klondike"; "The Origin of Bacteria from Algae," Dr. C. Louenstein, illustrated.

*Zeitschrift für den Physikalischen und Chemischen Unterricht* for November: H. Lüdtke, "Ein Farbengalvanoskop"; Looser, "Kleine Beiträge zur Optik"; A. Stroman, "Ein Demonstrationselement und eine Spannungsbatterie"; K. Bangert, "Versuche zum Nachweis der magnetischen Kraft bei elektromagnetischen Wellen auf Drähten"; H. Dircks, "Die Wirkungsgrösse der statischen Elektrizität"; Fr. C. G. Müller, "Kritische Bemerkungen zur neuesten Methode der Einführung der elektromagnetischen Einheiten im Unterricht"; E. Grimsehl, "Erwiderung auf 'Kritische Bemerkungen' des Herrn Fr. C. G. Müller"; E. Grimsehl, "Nachweis der Proportionalität zwischen der Stärke eines Stromes und der Stärke eines Magnetfeldes."

## LIMITS IN ELEMENTARY MATHEMATICS.

By G. W. Greenwood, Dunbar, Pa.

While crude ideas of limits may be, and probably are, entertained by everyone, placing their consideration upon a logical basis presents difficulties so great that such attempts may be most profitably omitted in a course in elementary mathematics.

Attempts are made to illustrate limits by concrete examples as well as by numerical operations. We use such hypothetical cases as that of taking half an apple, then half of the remainder, and so on, to show that one may be able to come as near as he pleases to getting the whole apple but can never get quite all of it. This of course implies the infinite divisibility of matter, though no one can conceive of anything infinitely divided, nor yet of a limit to the number of equal pieces into which it may be divided; in physics, however, for a long time most people accepted the "indivisible atom" as the last resort; in geometry we accept the former impossibility. Such illustrations, however interesting to the mature student who is philosophically inclined, serve but to entangle unsuspecting novices in the web of long-standing and wholly unsettled questions.

Next, we inscribe in a circle a regular polygon of many sides and assume that as the number of sides is "indefinitely" increased the length of the perimeter approaches that of the circle—a statement neither conceivable nor logically defensible; we have not defined the length of a curve, for one thing. A curve is "a line, no part of which is straight"; and to define something by what it is *not* affords slight foundation for establishing its properties. From this definition it is not possible to show that a curve has any length at all. It is customary to inscribe a square or a hexagon and to proceed by doubling the number of sides, though it is tacitly assumed that any regular polygon may be chosen initially and the number of sides increased in any manner. However, even in the comparatively simple cases of a square and a hexagon, the writer would welcome a *proof* that the series of perimeters obtained by doubling the number of sides tend to the *same limit*.

Of course we see, literally, that a circle and an inscribed regular polygon of a large number of sides are almost indistinguishable, but by making a zigzag line from one corner of a parallelogram to another along a diagonal, like a stairway, paralleling first one side and then an adjacent side, we see in like manner that this broken line will also be indistinguishable from the diagonal if the steps be small enough, but its length will remain half the perimeter of the parallelogram and never approach the diagonal.

From an algebraic standpoint we take the well-worn series

$$1 + \tfrac{1}{2} + \tfrac{1}{4} + \tfrac{1}{8} + \ldots$$

as an example of a variable approaching a limit. As it is easy to see that this series is convergent and that it approches a known limit —a number already familiar to the student, such an example may

well be used as an introduction to a study of limits as represented by infinite series. Some critics, however, professing to explain away the difficulties of the subject, make the mistake of confining their explanation to such a series, overlooking the fact that in most cases it is quite difficult to show that a series is convergent and even then its limit may not be obvious; it may even, so far as we know, be merely postulated, having no existence apart from the series we are considering, and all its approximations may be furnished by the series itself.

Consider the following example: Extract the square root of 3, add 2, and extract the square root of the sum; again add 2 and extract the square root; continue this process as often as you please and finally subtract the result from 2 and extract the square root of the remainder. (We are assuming that this subtraction is arithmetically possible; is this evident?) Now multiply this result by 2 as many times as you have extracted square roots, and then multiply once by 3. Now can you see that if this process were continued "indefinitely" the result could be made to differ from $\pi$ by as little as you please? Or do you rather have no idea what the limit would be? Yet this complicated process and unfounded conclusion are what we assume when we begin with a regular hexagon inscribed in a unit circle and proceed to double the number of sides with the expectation of proving that we approach a limit—namely, the length of the unit circle. We probably all agree in accepting the conclusion, but in geometry, as in most other subjects, conviction is frequently based neither upon demonstration nor logic.

By beginning with an inscribed square we get an entirely different series of operations and assume, with as little justification, that it tends to the same limit; in fact, we assume that by beginning with *any* regular inscribed or circumscribed polygon and increasing the number of sides in *any* manner we approach the same limit, though to justify this assumption would probably be beyond the powers of any mathematician. The writer feels that any attempt based on trigonometry or higher mathematics would be arguing *in* a circle as well as about it, because the data would implicitly involve the length of a circle to begin with; it would be like the "proof" that the solar parallax is exactly 8″.8, based on results obtained from the nautical almanac!

It would doubtless be impossible to place an elementary evaluation of $\pi$ on any other than an empirical basis. For this purpose it would be a great advantage to the student if he were taught in arithmetic when multiplying by a decimal, to begin with the left-hand digit and to obtain results correct only to a certain stated number of places; at present the figures of least significance receive wholly undue prominence because they are first used in obtaining the result. Were the other system adopted, not only would much time be saved, but a proper sense of relative values would prevail; students would see that a large number of decimal places is not necessary, neither are the extra figures in the way. We should learn to use irrational numbers as we use a fifty foot tape line, by drawing out as much of it as is needed and taking no account of the remainder.

Let us begin with a regular inscribed, and a regular circumscribed, hexagon, and proceed to double the number of sides, computing the

perimeters of each pair of polygons. It will be found that the former increases and the latter decreases, but always remains the larger of the two; but to *prove* these statements involves more assumptions or "axioms" than are found in current texts. If we now *assume* for the circle a property called *length*, intermediate in value between successive pairs of perimeters, this value will thus be found to a few decimal places and may be carried to as many as might be desired by the student. It may be stated, or found, that the same result will be obtained by starting with squares instead of hexagons, both being carried to the same degree of approximation. Such a method does not pretend to obtain the value of $\pi$ by a logical deduction from geometrical assumptions; it is purely empirical.

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## ADDITIONS AND ALTERATIONS TO BE MADE IN THE PRELIMINARY REPORT OF COMMITTEE ON GEOMETRY PRESENTED TO MATHEMATICS SECTION, CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS DECEMBER 30, 1906.

Section 1, last sentence, substitute the following: The committee expects no sudden drastic reforms in the teaching of geometry but hopes that those who may have been accustomed to look upon current texts as ideal and their logic unassailable will tolerate criticism and conceive the desirability of reforms.

In any event it is not advised that many changes be introduced hastily, but that, so far as possible, the teacher become familiar with each change before putting it into practice in teaching.

Section 3, second sentence, last clause, substitute the following:

It is recommended that the word "congruent" and the symbol $\equiv$ or $\cong$ be used to indicate this relation between two figures. The idea of congruence may be more clearly impressed by the use of "tracing paper," or any semi-transparent paper, first constructing any figures and then making tracings to represent figures congruent to them, superposition being a fundamental aid in a beginner's course in geometry; also by paper cutting and paper folding; the latter is of value in connection with the idea of symmetry.

Section 5, page 2, introduce the second paragraph thus:

It is not believed that a list of assumptions could be framed which would prove satisfactory to all, or that there would be any agreement as to which ones should be made tacitly and which explicitly; the following list is suggested, however, for a course in plane geometry, it being suggested....

Section 5, change the following assumptions to read thus:

A 10. Through a point not on a line we cannot draw more than one parallel to the line.

A 11. A sect determined by two points on "opposite" sides of a line is intersected by the line, and a sect determined by two points on the "same" side of the line is not intersected by the line.

A 12. Put the word "internally" in parentheses and insert or omit it according to the definition of the term "side."

Section 5, add the following assumptions to the list of those made explicitly:

A 18. A line through a point within a circle intersects the circle.

A 19. A sect whose end points lie one within, the other without, a circle, is intersected by the circle.

A 20. If a circle has a point within and a point without a second circle, the circles intersect.

Section 5, Assumption 3, second group:

The consecutive lettering of vertices of a polygon and of points on a line.

Section 8, omit the last statement in reference to the proposition in solid geometry.

Section 15:

"... the more careful study of a much smaller number of propositions and their applications... "

A new section:

## RECREATIONS.

It is believed that recreations and paradoxes not only excite interest, but have a distinct pedagogical value as well, and that some time could profitably be spared for their study. To discover a fallacy in a proffered demonstration is a most effective method of insuring the student's guarding against an error of such a character in his own proofs. It is perhaps not so generally known that the work of Euclid originally contained such examples, but unfortunately that portion of the text has been lost.

Examples of geometrical recreations and paradoxes can be found

G. W. GREENWOOD, Chairman.

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## CHEMICAL PROOF ANILINE BLACK STAIN FOR WOOD.

BY A. C. NORRIS,

*Rockford, Ill.*

Here is a recipe for a stain and wood filler that is as near chemical proof as can be expected. It is of a beautiful greenish black tint and does not show ink or dirt. We have put it on all of the laboratory tables and demonstration desks in our new laboratories. It is also used in the chemical laboratory in the University of Wisconsin.

Solution A—125 grams of copper sulphate and 125 grams of potassium chlorate are dissolved in a liter of water by heating.

Solution B—120 grams of aniline oil and 180 grams of concentrated hydrochloric acid are dissolved in a liter of water.

Two coats of solution A are applied while hot by means of a brush, the second one being put on as soon as the first one is dry. Two coats of solution B are next applied and the table allowed to dry thoroughly. A coat of raw linseed oil is then applied with a cloth so as not to use too much oil. A thorough washing with hot soapsuds completes the treatment.

## THE AUTUMN CONFERENCE IN MATHEMATICS AT THE UNIVERSITY OF CHICAGO.

The number in attendance at the departmental conference in Mathematics was about sixty, representing some forty-five schools. The discussion on the topic: *What should be the scope and purpose of first year work in Algebra*, was led by four representatives of widely different relations to the school system, all of whom are engaged in an active campaign for the improvement of teaching algebra and among whom there was substantial agreement in certain fundamental points as follows:

(1) There is need for careful reconsideration of the scope and purpose of algebra in the first year of secondary school.

(2) At present too much complicated and abstract work in algebra is introduced in the first year. While ample drill work on the processes is absolutely necessary, yet it is more important to drive home the few fundamental principles on oft-repeated single exercises than to utterly discourage the pupils with continued complicated manipulations which require hours of his study time.

(3) Theoretical and demonstrational presentation of algebra is not fitted to the age and maturity of the first year pupil.

(4) The solution of problems should form the central theme for the first year. These should be concrete, interesting, and connecting with things related to life. New processes should be introduced as they are needed in handling problems, and when so introduced should be drilled upon until they are thoroughly familiar. Concrete geometry and physics should furnish large and rich sources for problems. While neither demonstrational geometry nor experimental physics should be taught in the algebra to the first year pupil, yet the simple and easily recognized facts of both these subjects are easily within the reach of his comprehension and interest.

(5) All of the work of the first year should be developed out of and tied to arithmetic. The chasm between arithmetic and algebra should be closed.

(6) The foregoing points of view compel a readjustment in order of topics. Instead of crowding the first four or five months of the year with abstract and complicated manipulations in long multiplications and divisions, fractions, factoring, highest common divisor, lowest common multiple, etc., for which the pupils never find any use in application, either here or anywhere, much of this work should be put late in the year (much indeed should be left out entirely from the high school requirements, and included only in the later course to be elected by those preparing for college).

In this way space and time will be gained for solving problems and for helping both the pupils who may go to college and those who will not to see that algebra is not a mere juggling of symbols but is a practical tool for interesting, useful, and immediate service.

The speakers were: Superintendent C. M. Shelton of Crystal Lake, Ill., who is working out a plan on these lines both in the high school

and in the grades, Supervising Principal Paul G. W. Keller of Manitowoc, Wis., who is producing results in the way of added interest and power in the study of algebra, Mr. G. A. Harper at the New Trier Township High School, Wilmette, Ill., who is enthusiastic over the problem point of view in algebra as against mere abstract manipulation, and Mr. J. H. Dickey at the Academy of James Millikin University, Decatur, Ill., who is a strong advocate of reform along the lines mentioned above and is getting results to justify his ideas.

The papers are printed in full in the February number of the *School Review*, which is devoted to a complete discussion of the conference in all departments.

H. E. SLAUGHT, Chairman.

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## NEW YORK PHYSICS CLUB.

The forty-third regular meeting of the club was held in the Erasmus Hall High School, Brooklyn, on Saturday, November 23, 1907. About 40 members were present. The members were shown the laboratories and other equipment of the school and were interested in a wireless telegraph station which had been installed by pupils of the school. A practical test of this station was furnished during the day when a message was handed to President Woodhull which had been received by the wireless outfit. This message was an invitation to Mr. Woodhull to visit and inspect another wireless outfit which had been installed in another part of Brooklyn by pupils of another school.

The members listened to an address of welcome by Dr. W. B. Gunnison, Principal of the Erasmus Hall High School, in which he spoke of the school as the oldest secondary school in New York state; of the pride they felt in the original building, still standing and used for school purposes. Among the early patrons of the school were Alexander Hamilton and Aaron Burr.

By means of a lantern and by other experiments, Mr. R. H. Burnham demonstrated Rayleighs' principle of reciprocal deflection. This was done as follows: two points were taken equidistant from the ends of a uniform glass rod, and at one of these points a weight was hung. The deflections of both points (magnified) were then noted on the screen. The weight was then transferred to the other point on the glass rod and the deflections again noted. The deflections were just reversed to what they were before. An irregular glass rod was then taken and the weight hung near one end as before. Then the weight was put in the reciprocal position and the deflection noted. They were again reversed. The same principle was shown by hanging a weight at different points of a vertical spring.

Mr. F. W. Huntington explained and demonstrated Stoke's principle of dynamic similarity. This principle may be stated thus: two elastic bodies of similar shape whose linear dimensions are as 1:2 will vibrate in periods which are as 1:2. This was illustrated by (1) two bottles, (2) two brass rods, (3) two stretched wires, and (4) two coiled vertical springs. In all cases the linear dimensions were as 1:2, thus making the volumes 1:8. In the first three cases the vibratory periods were

compared by observing the relative pitch obtained from each object compared when sounded together. This was done by blowing over the mouths of the two bottles, by striking the brass rods with a piece of metal, and by plucking the stretched wires. In all these cases the tones produced were an octave apart. In the last case the rate of vibratory motion was directly observed and the periods were as 1:2.

Mr. H. S. Curtis gave a short talk on the teaching of some parts of light. He advocated the use of a piece of plane glass, *e. g.*, a lantern slide cover glass with a piece of dark paper for a background, in place of a plane mirror with silvered back in the exercises where a plane mirror was used; also that a stiff piece of cardboard with very narrow slits held vertically in the path of a sunbeam could be used to show the path of a ray to individual pupils in the laboratory when used in connection with a plane mirror to reflect the rays. The path of a refracted ray can be shown in the same way by making a somewhat wider slit and using a prism. A curved cylindrical mirror in the path of the refracted beam shows the recombination of the dispersed beam into white light.

Mr. E. L. Von Nardroff delivered a lecture illustrated by many experiments on the Physics of Sand. He considered first the conditions that must exist to produce normal piling. This is actually found in cannon balls regularly piled. The normal condition of a ball in a regular pile is found when each ball in the pile is touched by 12 others. Sea shore sand is round and approaches the typical spherical form the more rubbing it gets. The difference between normal piling and loose piling can be shown by placing a liter of sand in a graduate then gently tapping the cylinder containing the sand for some minutes when the sand was found to occupy 890 c. c. When the graduate was inverted with the hand held over the top to prevent the sand from running out and then reinverted to its usual position, the sand again occupied 1 liter. Other experiments showed the angle of slope in a loose pile; the angle of slope in a normal pile; the coefficient of friction. Many ingenious experiments were shown to illustrate the transmission of pressure by sand; the behavior of sand when partly filled with water; its mobility when wet and normally piled and when dry; its rate of flow. It is hoped that this lecture, together with the other demonstrations, will be published in full in SCHOOL SCIENCE AND MATHEMATICS.

R. H. CORNISH.

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## ASSOCIATION OF OHIO TEACHERS OF MATHEMATICS AND SCIENCE.

The Association held its fifth annual meeting in Chemical Hall, Ohio State University, Columbus, O., December 26 and 27, 1907. The attendance was the largest in the history of the Association and over forty new names were added to the membership roll. President J. A. Culler, Miami University, Oxford, presided over the science section, and Vice-President M. E. Graber, Heidelberg University, Tiffin, had charge of the mathematics section.

The following program was carried out:

GENERAL SESSION.

"What Should be the Minimum Equipment in Mathematics and Science of a Teacher of Mathematics in a First Class High School?" Prof. B. F. Yanney, Mt. Union College.

MATHEMATICS SECTION.

"What is the Best Curriculum in Mathematics for Present-day Needs of High School Pupils?" Miss Daisy M. Scott, North High School, Columbus; "Comparative Opportunities for the Study of Mathematics in American and German Universities," Prof. Wm. DeWeese Cairns, Oberlin College; "Originals in Geometry," Mr. H. H. Frazier, Tiffin High School; "The Mathematical Requirements of the Technical Schools," Prof. DeLonza T. Wilson, Case School of Applied Science.

Three-minute Discussions—"The Teaching of Zero and Infinity in the High School," Miss Grace Weston, Galion High School; "Defects in Present Methods of Teaching Secondary Mathematics," Prof. Fred L. Pauly, Lebanon University; "What Should be Emphasized in the Teaching of Arithmetic?"

SCIENCE SECTION.

"The Teaching of Physics in Secondary Schools," Mr. Lynn B. McMullen, Shortridge High School, Indianapolis, Ind.; "Coal-tar Compounds and Their Uses" (illustrated), Prof. Wm. McPherson, Ohio State University; "The Electron," Prof. A. A. Atkinson, Ohio University; "The Use and Abuse of Chemical Equations," Prof. Geo. F. Weida, Kenyon College.

Three-minute Discussions—"Which will be of More Value to a Man in Professional or Business Life, Physics or Chemistry?" Supt. Stanley Lawrence, Ashville; "How May the High School and Grade Mathematics Better Prepare for the Study of Science?" Mr. A. W. Dorr, Mt. Vernon High School; "What is the Use of Writing up Experiments in Physics?" Mr. Chas. H. Lake, East High School, Columbus.

A number of interesting and suggestive experiments were performed by members of the Association. Prof. Wm. Lloyd Evans, Ohio State University, gave a very interesting modification of the experiment illustrating the diffusion of gases. Prof. G. O. Higley, Ohio Wesleyan University, performed several experiments admirably illustrating the effect of mass upon chemical equilibrium.

At the business sessions resolutions were adopted relative to recent death of Prof. W. H. Wilson, Wooster University, who was a former president of the Association. Delegates were appointed to represent the Association at the Chicago meeting of the American Federation of Teachers of the Mathematical and Natural Sciences. The constitution was amended making the annual dues hereafter fifty cents instead of one dollar.

The officers elected for the ensuing year are: President, B. F. Yanney, Mt. Union College, Alliance; Vice-President, Wm. Lloyd Evans, Ohio State University; Secretary-Treasurer, Ralph W. Buck, East High School, Dayton.

RALPH W. BUCK, Secretary.

## REPORT OF THE MEETING OF THE ASSOCIATION OF TEACHERS OF MATHEMATICS IN THE MIDDLE STATES AND MARYLAND.

The ninth meeting of the Association of Teachers of Mathematics in the Middle States and Maryland was held at the College of the City of New York, Saturday, November 30. President Finley delivered an entertaining and cordial address of welcome, which was responded to by the president of the association.

The following amendment to the constitution was carried:

(To separate the offices, Secretary and Treasurer)

*Section III.* To be amended to read:

The officers of this Association shall be a President, a Vice President, a Secretary, and a Treasurer. These four officers with six additional members shall form the Council. The President, Vice President, Secretary, and Treasurer shall be elected - - - (*without further change*).

Professor Legras then presented a preliminary report for the Committee on Algebra Syllabus. It was reported that the committee had not yet agreed on the exact topics and amount to be taught in the first year of algebra, though some conclusions had been arrived at. It had been decided to exclude cube root from the High School work, and to leave inequalities for the second year. The committee asked for further time to consider the subject, and presented a printed list of topics, asking members of the association to suggest as to which should be taken up in the first year of algebra. This report aroused sharp discussion, and the committee was continued.

The first paper was by Charles D. Meserve, President of the New England Association of Mathematics Teachers. This paper was especially timely, as the two associations have recently decided to publish a joint bulletin, instead of separate publications. Dr. Meserve discussed the aims and progress of the New England Association, emphasizing especially its geometry syllabus, which has been very widely approved and adopted. He spoke very highly of the syllabus method of teaching mathematics.

In the afternoon, Eugene R. Smith of the Montclair High School discussed "The Coördinate Method as Applied to Plane Trigonometry." Mr. Smith said, among other things, that a function of an angle in the second, third, or fourth quadrant was negative if it contained, respectively, the abscissa, distance, or ordinate; and showed that this fact might be made the basis of all transformations of functions of angles in the form $N\pi \pm A$ to functions of A.

George Alvin Snook of Philadelphia Central High School spoke on "Geometry and Algebra for Knowledge or Power?" Mr. Snook took the position that pupils may acquire a great deal of power from the proper training of their mathematical faculties, and that the necessary facts can easily be acquired at the same time. He believed that certain of the methods of elementary algebra and some geometry theorems were beyond the pupils' original ability, and so needed development by the teacher and a receptive mind on the part of the pupil, but that many

sippi the production of hardwoods is clearly at its extreme height, and in Missouri and Texas it has already begun to decline.

other parts of the elementary work could be used as subjects for investigation and for acquirement of power. In the discussion of this paper wide differences of opinion as to the ability of pupils to do original work were shown. These opinions ranged from those who believed that pupils properly trained and guided could do a large share of the elementary work from an investigational standpoint, to those who believed pupils capable of little or nothing in this line. As a rule the speakers were optimistic as to the ability of the pupils.

The last paper of the day was an illustrated lecture on "Modern Calculating Machinery," by Professor Clifford B. Upton of Teachers' College. Professor Upton showed pictures of the various kinds of calculating machines, and gave a very clear and interesting discussion of their mechanism and use.

The following officers were elected for the coming year:

President, William Henry Maltbie, Woman's College of Baltimore.

Vice-President, William E. Breckenridge, Stuyvesant High School, New York City.

Secretary, Eugene Randolph Smith, Montclair High School, Montclair, N. J.

Treasurer, Emma Hazleton Carroll, Girls' High School, Philadelphia, Pa.

Members of the Council, to serve until 1910, Arthur S. Gale, University of Rochester, John J. Quinn, Scottdale, Pa.

It was decided to hold the spring meeting of the association in Baltimore. The association has been invited to join the open meeting of the Association of Teachers of History in the Middle States and Maryland on the evening of March 13th, and the regular sessions will be held on March 14th.

The reports of the committees and officers showed the association to be in a flourishing condition. Seventy new members have been added during the year, and the five sections are all active and progressive.

EUGENE R. SMITH, Secretary.

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## USE OF THE DIVINING ROD.

Numerous devices are used throughout this country for detecting the presence of underground water—devices ranging in complexity from the forked branch of witch-hazel, peach, or other wood, to more or less elaborate mechanical or electrical contrivances. Many of the operators of these devices, especially those that use the home-cut forked branch, are perfectly honest in the belief that the working of the rod is influenced by agencies—usually regarded as electric currents following underground streams of water—that are entirely independent of their own bodies, and many uneducated people have implicit faith in their ability to locate underground water in this way.

In experiments with a rod of this type, one of the geologists of the United States Geological Survey found that at points it turned downward independently of his will, but more complete tests showed that the downturning resulted from slight and—until watched for—uncon-

correct—that the operation of the "divining rod" is generally due to unconscious movements of the body or of the muscles of the hand. The experiments made show that these movements happen most frequently at places where the operator's experience has led him to believe that water may be found. The uselessness of the divining rod is indicated by the facts that the rod may be worked at will by the operator, that he fails to detect strong currents of water running in tunnels and other channels that afford no surface indications of water, and that his locations in limestone regions where water flows in well-defined channels are rarely more successful than those dependent on mere guesses. In fact its operators are successful only in regions in which ground water occurs in a definite sheet in porous material or in more or less clayey deposits, such as the pebbly clay or till in which, although a few failures occur, wells would get water anywhere.

Ground water occurs under certain definite conditions, and as in humid regions a stream may be predicted wherever a valley is known, so one familiar with rocks and ground-water conditions may predict places where ground water can be found. No appliance, either electrical or mechanical, has yet been successfully used for detecting water in places where plain common sense or mere guessing would not have shown its presence just as well. The only advantage of employing a "water-witch," as the operator of the divining rod is sometimes called, is that skilled services are obtained, most men so employed being keener and better observers of the occurrence and movements of ground water than the average person.—*U. S. Geological Survey Bulletin.*

## THE WANING HARDWOOD SUPPLY.

Although the demand for hardwood lumber is greater then ever before, the annual cut to-day is a billion feet less than it was seven years ago. In this time the wholesale price of the different classes of hardwood lumber advanced from 25 to 65 per cent. The cut of oak, which in 1899 was more than half the total cut of hardwoods, has fallen off 36 per cent. Yellow poplar, which was formerly second in point of output, has fallen off 38 per cent, and elm has fallen off one-half.

The cut of softwoods is over four times that of hardwoods, yet it is doubtful if a shortage in the former would cause dismay in so many industries. The cooperage, furniture, and vehicle industries depend upon hardwood timber, and the railroads, telephone and telegraph companies, agricultural implement manufacturers, and builders use it extensively.

This leads to the question, Where is the future supply of hardwoods to be found? The cut in Ohio and Indiana, which, seven years ago, led all other States, has fallen off one-half. Illinois, Iowa, Kentucky, Michigan, Minnesota, Missouri, New Jersey, Tennessee, Texas, West Virginia, and Wisconsin have also declined in hardwood production. The chief centers of production now lie in the Lake States, the lower Mississippi Valley, and the Appalachian Mountains. Yet in the Lake States the presence of hardwoods is an almost certain indication of rich agricultural land, and when the hardwoods are cut the land is turned permanently to agricultural use. In Arkansas, Louisiana, and Missis-

scious changes in the inclination of his body, the effects of which were communicated through the arms and wrists to the rod. No movement of the rod from causes outside the body could be detected, and it soon became obvious that the view held by other men of science is

The answer to the question, therefore, would seem to lie in the Appalachian Mountains. They contain the largest body of hardwood timber left in the United States. On them grow the greatest variety of tree species anywhere to be found. Protected from fire and reckless cutting, they produce the best kinds of timber, since their soil and climate combine to make heavy stands and rapid growth. Yet much of the Appalachian forest has been so damaged in the past that it will be years before it will again reach a high state of productiveness. Twenty billion feet of hardwoods would be a conservative estimate of the annual productive capacity of the 75,000,000 acres of forest lands in the Appalachians if they were rightly managed. Until they are we can expect a shortage in hardwood timber.—*Forest Service.*

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## REPORT OF THE COLORADO MATHEMATICAL SOCIETY.

The theory of limits in elementary geometry is the subject which has occupied the attention of the Colorado Mathematical Society for two meetings.

At the December meeting, the president, E. L. Brown, principal of North Side High School, Denver, stated that, the last meeting having been more or less iconoclastic, the discussion for that evening would be a constructive criticism of the theory of limits in elementary geometry, the leaders being Dr. Saul Epsteen of the University of Colorado, and Mr. Orville Price of the West Side High School, Denver. The President added that at the previous meeting Prof. H. H. Russell of the University of Denver had shown that the current method of handling limits is unsatisfactory, due partly to inherent difficulties, and partly to faulty modes of presentation. The Society was reminded that at the last meeting it had been the concensus of opinion that the incommensurable cases should be omitted from any first course.

According to Dr. Epsteen, the theory of limits is applied to two classes of cases; in the one the difficulties are those of incommensurability, as in the ratio between arcs, or between rectangles on equal bases; in the other the difficulties are those of curvature, as in the length of an arc, or in an area inclosed or partly inclosed by an arc. Neither class seems simple enough to be included in a first course for beginners.

In a first course the formal treatment of limits should not be attempted. Theorems involving ratios should be proved for the commensurable cases only, the truth of the general theorems being inferred from illustrations and approximations based on successively smaller units of measure. Theorems involving curved lines and surfaces should be proved as the ancient Greeks did it, by the method of exhaustions, values for the successive circumscribed and inscribed linear figures being clearly tabulated to show that the approximations may be carried to any preassigned degree of accuracy. At no time should any of the real difficulties, especially if raised by the pupils, be evaded

or covered up; on the contrary they should be met squarely, and assurance should be given that methods of overcoming them are provided in later courses.

Mr. Price called attention to the alternative methods proposed by Prof. Jones of Cornell University, and illustrated them by comparing one of them with the corresponding proof given by Wentworth.

Principal Brown gave a method based on the notion of the generation of a geometric magnitude at a uniform rate, recommending it, however, only for illustrative purposes. He heartily indorsed the alternatives of Prof. Jones, but insisted that any rigorous treatment would at the very outset require careful definitions of what is to be meant by the ratio of two incommensurables, the length of curved lines, and the area of curvilinear figures.

Professor Ira M. DeLong of the University of Colorado made the point that a comprehensive grasp of these abstruse notions and rigorous methods is of slow growth, and even though it be not possible to present these ideas in an entirely satisfactory way, yet it might be a mistake to omit their consideration altogether.

The Society took no formal action on any of the points brought out in the discussion; it was agreed, however, that for a first course rigorous definitions and proofs should not be attempted in the treatment of curves, limits, and incommensurables, this part of the subject being reserved for a later course.

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## REPORT OF EARTH SCIENCE SECTION OF THE CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS, ST. LOUIS MEETING.

At the section meeting on Friday afternoon, Mr. Armand B. Miller discussed introductory work in geography, using as the basis for his talk the course of study in Home Geography as used in the St. Louis public schools. Mr. Miller brought out very clearly the character of material to be used and how it formed a foundation for the later work in geography.

Mr. J. Andrew Druschel gave a very interesting paper on the "Loess Deposits about St. Louis."

On Saturday two trips were taken by members of the Earth Science Section. The first was to see the valley of the Mississippi river and study the erosion work in the bed. The second, to see not only the flood plains and bluffs of the river, but the processes in the manufacture of zinc at the Edgar Zinc Works. It had been planned to go through the St. Louis Blast Furnaces also, but an accident a few days before made it impracticable.

The following officers were elected on Saturday morning for the coming year: Chairman, Mr. James H. Smith, Austin, Ill.; Vice-Chairman, Miss Louise Sawyer, Elgin, Ill.; Secretary, Mr. L. L. Everly, Winona, Minn.

## CENTRAL IOWA ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS.

The fourth meeting of the Central Iowa Association of Science and Mathematics Teachers was held Friday evening, December 6, at North High, Des Moines. An informal luncheon was served, after which the following program was given:

The Overlapping of High School and College Science—Prof. D. W. Morehouse of Drake University discussed the overlapping in physics. This is due mainly to the fact that the student prepared in the high school has not had the necessary mathematics to take college physics and not until a course in physics is outlined which will require less mathematical preparation will the student coming from the high school be able to continue his work in physics without some overlapping. Such a course was thought practical. Do not have less physics but, if it is possible, have two years' work in physics which will not involve higher mathematics.

Prof. C. N. Kenney of Drake University discussed the overlapping in chemistry. He would solve the problem by having no high school chemistry. Chemistry has no place in the high school, but, if it must be taught, let it be mainly descriptive. Create a liking for the subject. Leave laws and theories for advanced work, and let only those who do not intend to take chemistry in college and who will need it in later lines of work study high school chemistry. It is generally conceded that students who have had chemistry in the high school are the most unsatisfactory workers in college laboratories.

Prof. George F. Dasher of Des Moines College discussed the overlapping in botany. The time intervening between high school and college botany solves the problem of any possible overlapping. The main object in high school botany should be to create a love for nature.

In the general discussion which followed, the high school people expressed the hope that a solution of the problems might be reached through a more thorough inspection of the high schools by the colleges.

Reports on the St. Louis meeting of the Central Association of Science and Mathematics Teachers were given. Miss Zulema Kostomlatsky gave a report of the biological section; Principal Ricker and Mr. F. E. Goodell the physical section; and Mr. W. L. Jordan the mathematical section.

Principal Maurice Ricker, West High, gave a talk on physiography. It was illustrated by views from the Flint River Valley in the vicinity of Burlington, Ia. The talk was very interesting and showed the possibilities in field work not only in physical geography but in botany and zoölogy. Mr. Ricker closed his talk with the suggestion that regions about Des Moines be worked up in a similar way.

At the business meeting the following officers were elected for the ensuing year: Miss Zulema Kostomlatsky, West High, president; Miss Maud St. John, East High, vice-president; Prof. D. W. Morehouse, Drake University, secretary-treasurer; Mr. A. W. Merrill, West High, and Miss Maria M. Roberts, State College, executive committee. F. C.

## PIPE LINES OF THE EASTERN OIL FIELDS.

The petroleum of the Appalachian oil field is transported almost entirely by pipe-line companies.

In the pipe-line method of transportation the separate tanks at each well in the oil fields are connected by small pipe lines to a large tank at a general receiving station for the district. The station is situated, where possible, on land lower than the location of the producing wells, so that the oil in the tanks at the wells will flow by gravity to the main receiving station. Where this is not possible the oil is forced to the receiving station by small pumps run by gas or other engines in the field.

At the main receiving station are large and powerful pumps of the highest mechanical efficiency, run by triple-expansion engines, the steam being furnished from boilers of from 300 to 350 horsepower. These pumps draw the oil from the receiving tanks and force it into the main pipe lines under pressure of from 600 to 800 pounds to the square inch. The main pipe lines are usually 6 to 8 inches in diameter, laid in straight lines over hills and valleys from one pump station to another. The pump stations are located from 30 to 50 miles apart. The main trunk lines are capable of transporting from 20,000 to 30,000 barrels of oil in 24 hours.

In the transportation by pipe lines there is a loss of oil, due mainly to three causes—leakage from pipes and tanks, evaporation, and the formation in the tanks of B. S., the brown sediment from the partially solidified paraffin. To compensate for this loss, 2 per cent is deducted from the actual measured quantity of oil taken from each tank. The runs of a pipe line represent the number of barrels of oil received from the tanks at wells after this deduction of 2 per cent has been made. The shipments of a pipe line represent the number of barrels of oil delivered to the refineries or other consumers of oil. The net stock of a pipe line is the actual quantity of merchantable oil that a pipe line has in its tanks or pipes. This stock does not always check with the difference between the quantity received and the quantity delivered, owing to the receipt of 2 per cent in excess of the quantity credited to the runs and to the loss from different causes. Besides runs and shipments, the pipe lines have irregular receipts from and make irregular deliveries to other pipe lines.—*U. S. Geological Survey Bulletin.*

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## BOOKS RECEIVED.

Haskins' Organic Chemistry. $2.00 net. John Wiley & Sons, New York.

Gage's Principles of Physics, revised by Arthur W. Goodspeed. 12mo. cloth, 547 pages; mailing price, $1.60. Ginn & Co., Boston.

## BOOK REVIEWS.

*New Course of Study for the Common Schools of Illinois;* fourth general revision, 1907. 9×6 inches; 279 closely printed pages. 30 cents a copy, postpaid. C. M. Parker, Taylorville, Ill., Publisher.

This is one of the most complete and comprehensive courses of study for the common schools published in any state. It is a complete compendium of what to teach and when to teach it. No common school teacher who desires to be up-to-date can afford to be without a copy. We cannot do justice to the book in the space allotted to us. The committee on revision consisted of ten of the most prominent school men in the state, with County Superintendent Charles McIntosh of Piatt county editor-in-chief. This committee in turn was assisted by twenty-seven other school men each prominent in his special line of work. More than two thousand teachers, too, have assisted in the work by sending to the committee suggestions for improvement in the course of study as they have encountered them in actual teaching. The course of study, then, is a book gotten out by the teachers for the teachers and their pupils. A short historical sketch is given. The introduction tells how to begin work. The pages on reviews and examinations are full of helpful suggestions as to how these divisions of the school program should be conducted. Then follows a general discussion of the outline of the course by years. Each subject, in any particular year, being discussed to considerable length, many details being brought out so that a teacher will know, in a general way, just how to proceed with her class. Lists of texts, readings, and reference books are given with nearly every subject. Morals and manners, agriculture and wood-working receive attention. A higher course for rural schools is also outlined, as well as a high school course where only one or two teachers conduct the work. Suggestions as to how to organize and manage boys' and girls' clubs are given. The school library, too, is not forgotten. The book, in fact, is a combination hand-book for teacher, pupil, and parent, and cannot fail of placing the common schools of the states that make use of it on a high plane of efficiency. S.

*High School Algebra, by J. H. Tanner, Ph.D., Professor of Mathematics in Cornell University.* Pp. vi+346. $1.00. American Book Company, 1907.

This text covers substantially the same ground as the "Elementary Algebra" by the same author, but presents a briefer and simpler treatment. Attention is invited to the following features: "(1) the careful statement of definitions and principles; (2) the emphasis laid upon translating formulas and equations into verbal language, and *vice versa;* (3) the inclusion of many formulas from physics which the pupils are asked to solve for the various letters which they contain; and (4) the extensive cross-references, as well as the many 'hints' and 'suggestions' found among the exercises and problems, all calculated to throw side-lights upon the work."

The author has kindly collected all the graphs into one chapter so that they may be easily omitted. The lists of problems are good.

H. E. C.

*Computation and Mensuration, by P. A. Lambert, Professor of Mathematics, Lehigh University.* Pp. ix+92. $.80. The Macmillan Company, 1907.

The author in the preface states his belief that the transition from secondary school to college, which is disastrous for many students, is due largely to the fact that the student has not been taught to make independent use of what he has learned. Upon this text-book a transition course may be based which would come naturally at the end of the secondary school course or at the beginning of the college course.

The chapters of most interest, possibly, to the secondary school teacher are: Chapter I, Approximate Computation; II, Graphic Computation; IV, The Prismatoid; V, Computation and Use of Trigonometric Functions; and VI, On Limits. Of the one hundred and sixty-five problems the number of real live problems is small. It seems to the writer that the place to begin approximate computation is in the first year algebra, and that such work as is suggested in this text-book should be continued from the beginning to the end of the high school course, and then continued to the end of college mathematics. H. E. C.

*The Moon in Modern Astronomy, by Philip Fauth, translated by Joseph McCabe, with an Introduction by J. Ellard Gore, F.R.A.S., M.R.I.A., etc.* Pp. 160. Price, 10 shillings. A. Owen & Co., London.

The reader of semi-popular science has not of late years been surfeited with books on the moon. Barring the usual references from time to time in the daily press to certain grotesque nothings that our satellite has reluctantly yielded up to some industrious aspirant to sub-lunar fame the public has had to go hungry for lunar lore. Not a few of those who take a lay interest in astronomical matters have been more than a little disappointed that the great Lick and the greater Yerkes Telescopes have been so tardy in settling the mysteries of the lunar physiognomy as well as all doubts as to the moons habitability.

It must not be thought, however, that lunar astronomy has been languishing for lack of ardent students. The fact is that the period of the sensationalist in science is passing as regard the study of the moon. The earnest, patient, persistent devotee of scientific truth has displaced the sensation monger, and the "hunter for stimuli" There has not been a moment since Beer and Mädler in Germany in 1857 published their great map and accompanying "selenography," when the moon has lacked enthusiastic devotees. An immense fillip to lunar study was given by the publication by Julius F. J. Schmidt of his masterpiece, entitled: "Map of the Mountains of the Moon." Few among the astronomical laity are familiar with the significance of the wonderful photographic charts of the moon recently made at the Lick Observatory and at the Observatory of Paris. Excellent work has also been done on the moon in recent years at the Yerkes Observatory. This book reviews, critically estimates, and summarizes in easy language the work done in the study of the moon since the invention of the telescope.

The author, Fauth of Landstuhl, Germany, is himself a life-long

student of the moon, and from his first-hand familiarity with the matters he is discussing, his opinions must have weight. He deals fearlessly with the work of others, gives scant courtesy to the lunar work of American Astronomers, and in the closing chapter, entitled "Some Conclusions," expresses some striking views. For example: who was prepared for so brusque a sweeping away of the volcanic origin of lunar mountains, and for the conclusion: *"The moon is covered with a thick layer of ice"?*

The book is well written, well translated, and the publisher's work is nothing less than charming. Only a few unimportant typographical errors, such as "Drayer" p. 39, for "Draper" (Dr. John W.), have been found. Teachers and readers of popular science, equally with scientists, will find the book interesting—not to say racy—reading. It is commended to any who are interested in the historical genesis of our present knowledge of the moon. M.

*Essentials of Algebra, by J. C. Stone, State Normal College, Ypsilanti, Mich., and J. F. Millis, Shortridge High School, Indianapolis, Ind.* Pp. 462+60. $1.12. Benj. H. Sanborn & Co., Chicago. 1905.

It was the aim of the authors to write a modern and progressive book, free from fads and in no sense extreme. In ths they have succeeded, and the teacher who uses this book for a few years will surely catch the spirit of progress and look for a new text-book which is a little extreme. The explanations are clear and direct. The checking of results is insisted on from the beginning. The equivalence of equations is discussed early, and the frequent reference to this subject ought to lead the pupil to discard always extraneous solutions. The graph ought to be introduced earlier than it is, possibly, and used to solve problems. The large clear type and open page are to be commended.

H. E. C.

*An Elementary Study of Chemistry, by Wm. McPherson and W. E. Henderson.* Ginn & Co.

This text-book of 419 pages is prepared in such a way as to give the pupil who studies it a good general idea of the chemistry of to-day.

The definitions, laws, etc., are clearly presented in language that is readily understood. It is thoroughly modern and freer from misstatement and typographical errors than the average text-book.

The treatment of the topics acids, bases, and salts, ionization, reversible reactions, and catalysis is particularly good. The last twenty-one pages are devoted to simple organic compounds.

The book has a good index and about ninety illustrations. Questions like No. 5 on page 92, "To what is the blue color of liquid air due?" "Does this color increase in intensity on standing?" and No. 8 on page 93, "Would combustion be more intense in liquid air than in the gaseous substance?" should not be asked in the text-book and the student left to *guess* at the answers which are not suggested in the book and which most pupils will not be able to ascertain by experiment.

I found very few points to criticise in this book and regard it as one of the best texts available for high school use. A. L. S.

*Time and Clocks, by H. H. Cunynghame, M.A., C.B., M.I.E.E.* E. P. Dutton & Co., New York. Pp. 200. $1.50 net.

The numerous lists of reference books in physics for school libraries which are continually appearing are indications of the eagerness with which books suitable for such purposes are sought. Most of such books are text-books and frequently, while possessing full details of information, lack that readable quality which makes them attractive to young people.

Cunynghame's "Time and Clocks" is unique in its attractive form and interesting content. Subjects which are usually dry are vividly and accurately described. The fundamental measurements of space, mass, and time are made clear by references to mythology, literature, and history. Sun dials, sand glasses, mercury and water clocks, the pendulum clock of Galileo, notions of acceleration, gravity and falling bodies, the isochronism of springs are all compelled to lead delightfully to a real explanation of "harmonic motion," the cycloid and the interesting details of mechanism of a "grandfather's clock."

Reference books in physics that are both instructive and interesting are so difficult to obtain that teachers should welcome an opportunity to put into their pupils' hands a book that combines readable qualities, literary style and information on difficult topics.

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*Farm Weeds of Canada, by Geo. H. Clark, Seed Commissioner, and James Fletcher, LL.D., Botanist of the Dominion Experimental Farms, Department of Agriculture, Ottawa, Canada.* 103 pages. 8 vo. 56 plates in color.

This bulletin, published by the direction of the Minister of Agriculture for free distribution to the rural schools and farm homes of Canada, is the finest volume of its kind that we have seen. The large colored plates display in natural colors over 50 of the most troublesome Canadian weeds. The drawing and coloring are so accurately done that any school child or a farmer without botanical training could have little trouble in at once identifying the plants.

Dr. Fletcher's wide experience has enabled him to describe the different plants, and discuss the families to which they belong, with scientific accuracy and yet with such simplicity that the ordinary reader may understand the descriptions. Many of the more difficult botanical terms are defined in the introduction.

The methods recommended for the eradication of various weeds are only those which are practicable and that have proved successful in actual experiment. The importance of a knowledge of the habits of growth of a plant if we are successfully to combat its spreading is strongly emphasized.

The bulletin would make a valuable addition to any school library and will greatly assist any teacher of botany or nature study who is attempting to present this practical and important aspect of plant life.

GEO. D. FULLER.

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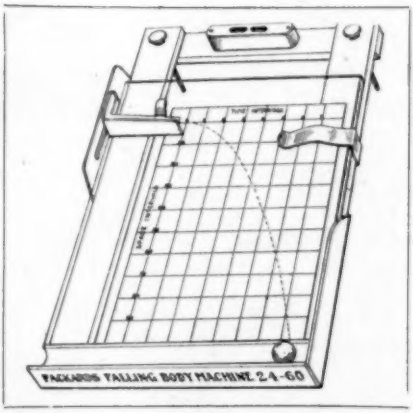


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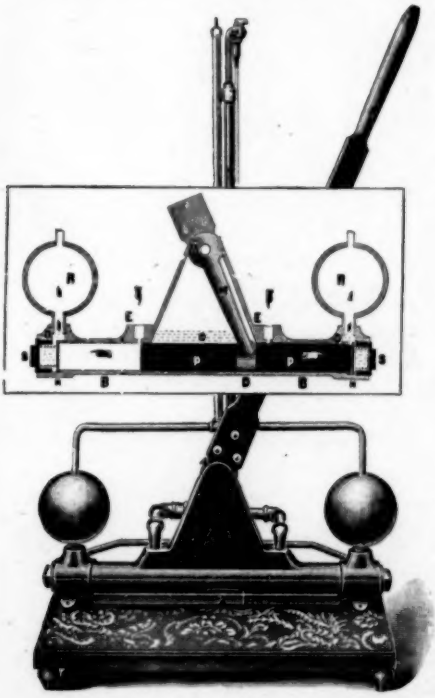

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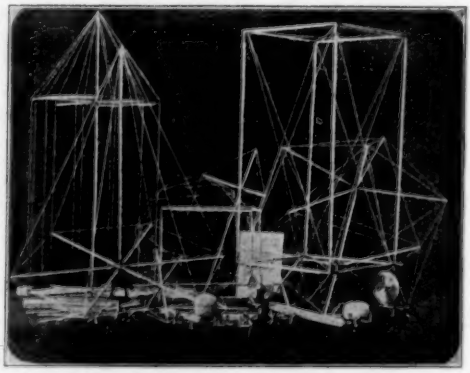

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